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The State of
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draft
environmental
impact statement

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DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR THE STATE OF MONTANA EMERGENCY GRASSHOPPER CONTROL PROGRAM

PLEASE RETURN

Prepared by the
Environmental Management Division
of the
Montana Department of Agriculture

June 1989

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PREFACE

Grasshopper population outbreaks occurred in numerous counties in Montana in 1985, 1986 and 1987. Board of County Commissioners from various counties petitioned the Governor to declare an emergency in each of the three years to make state monies available to farmers within these counties through the state emergency and disaster fund. The Governor, based upon these petitions and verifications of grasshopper infestations, declared an emergency each year. On June 15, 1987, the Environmental Quality Council (EQC) raised a question about the applicability of the Montana Environmental Policy Act (MEPA) to this action and whether any type of environmental review was necessary. The Montana Department of Agriculture (MDA) subsequently requested an Attorney General's opinion on the issue.

The Attorney General's opinion issued on February 5, 1988, held:

1. The participation of the state of Montana in a grasshopper spraying program in which the state pays up to one-third of the costs and provides financial management and technical expertise, is a major state action in which compliance with the terms of the Montana Environmental Policy Act is required.

2. While an emergency situation is a legitimate exception to the requirements of MEPA, the Montana Department of Agriculture should, in the future, comply with MEPA before participating in a grasshopper spraying program, if the need for such program is reasonably foreseeable.

In the text of the Attorney General's opinion he further stated that: "It appears that (a) programmatic Environmental Impact Statement (EIS) may be the desirable way for the Department to meet the requirements of MEPA and be able to respond readily when confronted by an immediate need to deter a grasshopper infestation."

According to MEPA rules, emergency programs are exempt from requirements of MEPA as long as a summary of the results and impacts of the emergency program are submitted within 30 days of the initiation of the emergency. Section 10-3-302 of the Montana Code Annotated provides that a state emergency may not continue for longer than 20 days. Under the emergency rules promulgated by the department, an additional

10 days was allowed for treatment to be completed. Thus, the entire program had to be completed in 30 days.

An accurate assessment of the impacts and results of this program can not be made without the analysis of similar non-treated land and land treated without state assistance. Baseline data must be collected prior to implementation of the program to determine the actual environmental impacts that occur. This requires knowledge of the site location prior to treatment. However, the site location and acreage to be treated under the emergency program are not known until the producer claims are submitted to the state approximately 3 months after initiation of the emergency program. Thus, reporting the results and impacts of the program within 30 days as required by MEPA is not possible the way the current emergency program operates.

This document is written only in reference to the emergency grasshopper control program, and thus only grasshopper and Mormon cricket emergencies should conform to the alternatives discussed in the document.

This document adheres to the rules of MEPA and meets the requirements of a programmatic EIS under MEPA rules. However, lack of environmental and efficacy data specific to the program limits the department's ability to make definitive recommendations with regard to a specific state grasshopper management program.

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CHAPTER ONE

INTRODUCTION

Grasshoppers and Mormon crickets have posed a serious threat to crop production in Montana since the late 1800's. Severe grasshopper outbreaks have occurred at inconsistent intervals in time and have been geographically widespread or isolated. In either case producers located in areas of grasshopper outbreaks may experience extensive crop loss, destruction of rangeland, and destruction of wildlife habitats, resulting in serious economic impact to the state.

Grasshopper outbreaks in Montana were quite severe during the years of 1985, 1986 and 1987. The populations of grasshoppers in several counties each year were dense enough to be considered an insect infestation which may be defined as an emergency in the Montana Code Annotated (MCA 80-7-501). The Montana Crop Insect Detection and Management Act of 1977 (MCA 80-7-504) provided a mechanism by which the state could assist in the control of grasshoppers on cropland through a cost share program. The act was never funded, but did allow for the use of emergency funds to assist producers with grasshopper control during widespread infestations (MCA 80-7-501(4)).

State emergency funds were thus allocated to assist in controlling grasshoppers in Montana in 1985, 1986, and 1987 following an emergency declaration by the Governor. The mechanisms by which a state of emergency may be declared for insect infestations required the identification and quantification of the severity of the insect pest by the Montana Department of Agriculture (MDA). Individual counties which were experiencing widespread grasshopper populations in excess of a set economic threshold of 8-9 adults/square yard (USDA-APHIS undated) were eligible for state assistance.

Following questions raised with regard to the applicability of the Montana Environmental Policy Act (MEPA)(MCA 75-1-101) to this emergency program, the MDA requested the Attorney General's opinion on this issue. On February 5, 1988, the Attorney General held that the State of Montana's participation in the emergency grasshopper control program which provided financial assistance and technical expertise is a major state action in which compliance with the terms of the MEPA is required. Though an emergency situation is a legitimate exception to the requirements of MEPA, the MDA failed to comply with the guidelines of MEPA by not submitting a summary of the results of the emergency program within the 30 days spacified in the MEPA rules to the EQC following each year it was implemented. In the text of the Attorney General's opinion he further stated that: "It appears that a programmatic Environmental Impact Statement (EIS) may be the desirable way for the MDA to meet the requirements of MEPA and be able to respond readily when confronted by an immediate need to deter a grasshopper infestation". This programmatic EIS was prepared to conform to the guidelines of MEPA and to address the use of state funds to assist producers in emergency grasshopper control.

The United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) currently assists in grasshopper control on affected federal and state lands, as well as on private land that meet federal program requirements. This rangeland block treatment program controls grasshoppers on rangeland in blocks of 10,000 acres or greater in size. Cropland may be treated within these blocks as long as it does not exceed 20% of the total acres. The cropland protection program (announced in APHIS Q's & A's in 1987) allows for treatment of federally owned rangeland adjacent to cropland in 1/4 to 1/2 mile strips. Thus there is no federal assistance available for grasshopper control on most cropland within the state.

This document is designed as a review of policy established by the legislature and acted upon by the Governor and executive branch agencies and the resultant effect on the environment. This document will investigate the current program and potential alternatives in which the State may act in the event of widespread grasshopper infestations. In addition, the document will address alternative actions available to the state during years of lower grasshopper populations in attempt to reduce the impact or occurrence of grasshopper infestations. It is not within the scope of this document to perform a thorough review or analysis of insecticides registered for grasshopper control.

The Montana Department of Agriculture adheres to the guidelines of the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) and the

Montana Pesticides Act (MPA) for the registration of pesticide products. Under FIFRA as amended any compound claiming pesticidal properties sold in The United States must be registered with the EPA (7 USC 136a, 40 CFR 162.1). Federal registration requirements are listed in 40 CFR, part 158, and include product chemistry, product composition, physical and chemical characteristics, residue chemistry, environmental fate, hazard to humans and domestic animals, reentry protection, pesticide spray drift evaluation, hazard to non-target organisms, and product performance (40 CFR 158.100 - 158.170). Only those pesticides which were registered by the EPA and concurrently registered in the state of Montana were used for controlling grasshoppers in the state emergency programs of 1985, 1986, and 1987. This program was enacted in response to an unpredictable emergency, thus water quality, wildlife populations, and human health were not monitored before or after the program. Grasshopper populations were determined prior to the initiation of the program; however, post program counts were not performed.

Information contained in this document is based on research evidence, individual observations, production figures, and historical information, which relate to the economic and environmental impact of the state emergency grasshopper control program.The EIS will almost exclusively discuss grasshoppers; however, the similarity in biology and control of Mormon crickets and their past occurrence as a significant crop pest in Montana require that this document also apply to Mormon crickets even though they are rarely discussed in the text. The following five chapters describe the impacts and potential impacts of the state assisted (cost share) grasshopper emergency program, alternatives available to the state if faced with another grasshopper emergency situation, and the possible mitigating actions (as alternatives) which might reduce the likelihood of an emergency. The chapters are broken down as follows:

a. Biology, control, and history of grasshoppers in Montana;

b. Current insect management programs in Montana;

c. The environment and economics affected by the current program;

d. Potential impacts of insecticides on the environment;

e. The alternatives considered by the state which may effectively reduce crop damage during infestations or reduce the likelihood of grasshopper infestations.

CHAPTER TWO

BIOLOGY, CONTROL AND HISTORY OF GRASSHOPPERS IN MONTANA

Grasshopper infestations have periodically had a significant effect on agriculture in Montana. They have caused economic hardship for farmers and ranchers and direct and indirect impacts to Montana's delicate ecosystem. The following chapter will briefly describe the biology of grasshoppers, nature and cause of severe grasshopper outbreaks, some of the available methods of grasshopper control, and the history of grasshopper infestations in Montana.

Biology of Grasshoppers

Of the approximate 125 species of grasshoppers that inhabit Montana only a few cause crop damage. This section will concentrate on those destructive species. Species most detrimental to crop and range production include (Gillespie 1988):

Migratory	grasshopper	(Melanoplus sanguinipes)
Twostriped	"	(M. bivittatus)
Packards	"	(M. packardii)
Redlegged	"	(M. femurrubrum)
Clearwinged	"	(Camnula pellucida)
Bigheaded	"	(Aulocara elliоti)
Whitewhiskered	"	(Ageneotettix deorum)
Striped Slant-faced	"	(Amphitornus coloradus)

Though the biology of each species differs to some degree, the following gives a general description of the life cycle and feeding habits of grasshoppers considered to be insect pests in Montana. Each life cycle consists of three distinct stages, known as the egg, nymph, and adult. Intermediate developmental stages exist within egg and nymphal stages.

Crop consuming grasshoppers of Montana are capable of only one generation per year. Adult females lay eggs in early summer to early fall. The eggs, encased in a pod, are deposited approximately 1 - 2" deep in the soil. The soil cover and pod help protect eggs from predators and the elements. The number of eggs per pod varies with species (Table 1.). The average number of eggs per pod for most species is 20, but some species may deposit pods containing 200 to 400 eggs (Gillespie and Wight 1985). In nature, females rarely deposit more than 4 - 5 pods/season.

Females generally lay eggs in soil which is not excessively moist and is near a readily available food supply in the spring. Ideal sites for egg laying include roadsides, field margins, pastureland, ditchbanks, headlands, fence lines, and conservation tillage fields. Undisturbed sites provide a higher rate of nymphal survival because fall or spring tilling tends to rupture egg pods, bring eggs to the soil surface (where they are consumed by predators), or bury eggs deep (which doesn't allow nymphs to reach the surface before they perish). Egg pods of most Melanoplus spp. are generally placed within the root zone at the base of grass stems or crop stubble. The big headed and whitewhiskered grasshoppers place eggs in small areas (6" diameter) of bare soil.

Table 1. Number of grasshopper eggs per pod for select species.

Species	Eggs Per Pod
Whitewhiskered	4
Bigheaded	3-11
Clearwinged	15-20
Migratory	15-20
Redlegged	25-30
Twostriped	50-100

Eggs begin development immediately following deposition and continue this process until it is arrested by an absence of heat or until a diapause develops. In the spring when ambient soil temperatures reach about 60 F (16 C) the eggs resume development. Depending on the

species of grasshopper and the stage of development, eggs begin to hatch 5-25 days following a break in diapause. Depending on temperatures and continued climatic variations the bulk of the eggs for any one species will continue to hatch over a 2-4 week period.

The first instar (stage) nymphs will usually begin to hatch in mid-May through early June. Eggs may hatch as early as late April if conditions are quite warm or hatching may be delayed in the event of a cool spring. As nymphs first emerge they begin to feed in their immediate vicinity. There are 5-6 nymphal stages, depending on the sex and species of grasshopper. Each stage lasts from 7 to 10 days and is termed an instar. The entire nymphal stage lasts 35 to 60 days.

Grasshoppers, as well as other insects, must shed their exoskeleton before they can reach the next stage of development in their life cycle. This process is termed molting. Once the old exoskeleton is shed the new cuticle is stretched through a series of muscular contractions in one area of the grasshopper's body, which produces external pressure in the uncontracted areas of the body. Once stretched in this manner the cuticle takes 1 to 3 hours to harden. During a molt, nymphs and newly emerged adults are extremely vulnerable to parasites, predators, disease, and weather. First and second instars will usually have the highest mortality rate of all the instars.

Nymphs are easily distinguished from adults by their smaller size and small undeveloped wings. Each succeeding instar is capable of consuming more food than previous instars. Nymphs, because of their undeveloped wings, are limited in their ability to move, thus increasing the likelihood of starvation if vegetation is limiting.

Adult grasshoppers emerge after the 5th or 6th instar molt (late June through October) with wings capable of flight. Mating and egg laying may begin immediately after females reach sexual maturity and depending on the species may continue for up to 6 weeks. The average longevity of the adult grasshopper is approximately 12 to 21 days. Adults are less susceptible to weather, predators, parasites, disease, and insecticides. Adults are capable of consuming great quantities of vegetative matter and have the ability to travel long distances in search of food, and thus have a greater potential for inducing crop destruction over a large geographic area.

Mormon Crickets

Mormon crickets, like most grasshoppers, complete only one generation per year. Crickets lay their eggs singly rather than in pods. Each egg is

placed just under the soil surface in bare spots between clumps of vegetation. Individual females lay approximately 150 eggs in late summer and early fall. Mormon crickets begin to hatch in early April and reach maturity in 6 to 8 weeks.

During unfavorable environmental conditions Mormon cricket populations remain low and are primarily restricted to rough foothill terrain. When weather conditions become favorable for several years, populations increase rapidly. In spite of having no wings Mormon crickets may migrate up to 1 mile per day in large bands in search of dense forage.

Nature and Cause of Grasshopper Infestations

Grasshoppers have been studied extensively throughout the United States over the last 100 years; however, little is known about how to predict grasshopper populations. Pepper (1975) pointed out that much of the research done between 1920 and 1970 addressed the biology of infestations. Very little was accomplished in determining the causes of infestations because of the complex interactions between grasshoppers, climatic factors, and types of vegetation. Most studies demonstrate that there is no way of predicting what will happen with grasshopper populations in one season based on a previous season's (Pepper 1975). However, Gage and Mukerji (1977) found a strong correlation between a seasons grasshopper densities and the densities of the previous year. Kemp (1987) has partially based a probabilistic model on this correlation, which appears to function relatively well. Future research may answer this question.

Research evidence and observation does suggest that particular environmental and climatic conditions encourage grasshopper outbreaks (Capinera 1987, Kemp and Onsager 1986, Hillbert and Logan 1981, and Hewit 1979). Succulent foliage must be present as a food source for recently hatched nymphs. Hot, dry spring weather promotes nymphal movement, feeding, survival, and development. Continued hot, dry weather inhibits pathogens and speeds up grasshopper development. Adults emerge earlier than normal and females have a longer period to lay eggs prior to the onset of cold weather. Late summer and early fall rains provide soil moisture required for egg development. Good egg laying conditions can increase the number of eggs laid, number of eggs that hatch, and the survival rate of first instar nymphs (Hewitt 1985). Cool, wet springs increase mortality (especially of first and second instars)

and slow growth and development of all instars which results in low numbers of adults and decreased egg laying time.

It is widely accepted that certain vegetative conditions can influence the buildup of grasshoppers. In general, poorly managed land appears to be a source of grasshopper problems. Many speculate that over grazing of rangeland may increase grasshopper populations. Anderson (1964) made the observation that prairie species of grasshoppers are favored by rangeland with total vegetative coverage of less than 40%. Increased forage production by rangeland scalping treatments appear to decrease numbers of grasshoppers (Hewitt and Rees 1974). Scoggan and Brusven (1973) suggest that semi-arid rangeland is ideal for grasshopper infestations and that range fires appear to encourage grasshopper populations. However, they also found that overgrazing primarily favors bandwing grasshoppers (i.e. Camnula pellucida), while well managed rangeland dominated by perennial grasses tends to favor slantfaced grasshoppers (i.e. Aulocara elliotti). Spurthroated grasshoppers (i.e. Melanoplus sanguinipes) are adaptable to either. Bill Kemp (1988) of the USDA Rangeland Insect Lab suggested that rangeland which has been grazed closely will decrease mortality rates among young grasshoppers as the reduced canopy increases ultraviolet light penetration and decreases the humidity of the microclimate. Both of these factors inhibit the activity of microsporidian pathogens of grasshoppers (i.e. Nosema locustae).

Grasshoppers have frequently been observed moving in large numbers from rangeland into cultivated land. Clean stands of most annual crops are not conducive to egg laying thus most grasshoppers during infestation years probably do not originate from producers fields. Pickford (1963) determined that grasshoppers have lower hatch and survival of nymphs in spring wheat fields than prairie grass fields; however, he also showed that grasshoppers raised on spring wheat were healthier and were able to lay up to 20 times more eggs than those raised on prairie grasses.

Grasshoppers cause crop damage either by cutting small plants off at ground level, stripping leaves, or clipping heads from mature plants (Pickford and Mukerji 1974). Greatest yield losses are caused by ground level cutting of young plants. Yield losses due to leaf stripping are most severe when defoliation occurs gradually throughout the season (Olfert and Mukerji 1983).

Eight to nine adult grasshoppers per square yard is the frequently accepted infestation level (economic threshold); however, the number of grasshoppers in a field does not correlate well with crop damage (Mukerji et al. 1976). Weather, soil moisture, geography, host variety, plant response, and grasshopper feeding habits appear to determine the extent of crop damage. The USDA Rangeland Insect Lab has recently

developed a computer "expert system" that takes many factors into account when determining the economic threshold for controlling rangeland grasshoppers with several control alternatives (Kemp et al. 1988). Crop variety appears to have a significant effect on extent of damage by grasshoppers (Olfert et al. 1988, McBean and Platt 1951 and Jacobsen and Farstad 1941). For example, some barley varieties sustained only leaf stripping whereas more susceptible varieties were eaten to the ground by large numbers of grasshoppers in a study by McBean and Platt (1951).

For grasshoppers to achieve an infestation they must overcome a host of predators and parasites. Eggs are consumed by field crickets and ground beetles and parasitized by scelionid wasps. Once the eggs hatch, nymphs and adults are preyed upon by insects, birds, mammals, spiders, mites, reptiles, and amphibians (Lavigne & Pfadt 1966). Predators include a number of birds (such as blackbirds, kestrels, robins, crows and game birds), wild mammals (coyotes and skunks), and amphibians (frogs). Parasites include parasitic wasps, flesh flies, tachnid flies, tanglewing flies, and nematodes. Many of these parasites are also hosts and prey to other organisms, thus making it a very complex food chain. Diseases of grasshoppers include the fungus Entomophaga grylli, entomopox virus, and the protozoan Nosema locustae (Street 1987).

In spite of this battery of potential biological control agents, grasshoppers have the biotic potential to develop sudden explosive population increases. Generally, grasshopper outbreaks develop following a gradual population buildup over several years. Thus, under favorable conditions populations may explode to numbers greater than 100 grasshoppers per square yard capable of completely destroying range and field crops.

Grasshopper Control

As stated earlier, grasshoppers pose an unpredictable threat to crop production in Montana. Generally, grasshopper control is not undertaken until an imminent problem exists. Presently, there are four primary strategies which are implemented to control grasshoppers:

1) Cultural Control
2) Insecticide Sprays
3) Insecticide Baits
4) Biological Baits

Cultural control methods may initially cost less than the other three methods; however, the decision to employ cultural control

must be made before planting regardless of whether or not grasshoppers might be a problem that season. Cultural control involves modifications of one or more of the normal practices employed by the producer. These modifications may alter the habitat or micro-environment in a manner that suppresses grasshopper populations or decreases their ability to reproduce. Examples of cultural control methods include early planting of spring grains, cultivation of soil to destroy existing eggs, and the use of trap strips. Trap strips are quite expensive to implement and generally give only a percentage of control. Trap strips are designed to collect nymphs or migrating adults into a small area where they can be more easily controlled. To control adult grasshoppers, trap strips are planted with barley in mid to late June along with a systemic granular insecticide.

The primary disadvantages of cultural practices are inconsistent and incomplete grasshopper control. These practices must also be employed prior to the presence of a grasshopper outbreak which further decreases their desirability. These methods are most effective in an overall management program that involves several methods of control.

The second control method is the use of insecticide sprays. Insecticide sprays were introduced in the late 1940's and have evolved since. Insecticide sprays are relatively inexpensive and are very effective when applied in a timely manner. Their ability to kill grasshoppers is readily observed. Insecticides and application equipment are readily available for producers use. Insecticide sprays generally achieve grasshopper mortalities of 95% or greater if they are applied prior to grasshoppers reaching adult stages. A major concern with current insecticide sprays is the short residual nature of the compounds which give control of grasshoppers for a maximum of about 3 weeks (Table 2).

Disadvantages associated with insecticide sprays include the following. The inherent toxicity of these compounds to applicators and other individuals that might be exposed to the insecticide residues. Spray and spray residues in the environment may result in poisoning of fish, birds, and mammals. Insecticides are generally not host specific and thus may kill non-target insects including honey bees and grasshopper predators and parasites. This may result in a more rapid build up of grasshopper populations following insecticide treatment, because the populations of natural predators were reduced (this is termed resurgence). A recent study by Lockwood et al. (1988) suggests that continuous use of insecticides in the control of grasshoppers in Wyoming

Table 2. Synthetic insecticides registered for grasshopper control on wheat, barley, corn, alfalfa, potatoes, sugar beets, beans, range and pasture, field margins, sunflower and safflower, and ornamentals and turf in 1987 (see Appendix A) and their approximate residual kill of grasshoppers (Gillespie 1988).

Common Name	Trade Names	Residual Kill (days)
Acephate	Orthene	6 - 9
Azinphos-methyl	Guthion	7 - 21
Carbaryl	Sevin, Sevimol, Sevin bait, Debug-Ag	7 - 21
Carbofuran	Furadan 4F	7 - 14
Chlorpyrifos	Lorsban 4E, Dursban, Orkinban 3E	7 - 10
Diazinon	Diazinon	7 - 10
Dimethoate	Cygon	10 - 14
Disulfuton	DI-SYSTON 8	10 - 14
Fenvalerate	Pydrin	7 - 10
Malathion	Malathion, Cythion, MA-LI-CIDE II	2 - 5
Methyl Parathion	Methyl Parathion	1 - 2
Mevinphos	Phosdrin	1 - 3
Naled	Naled 8, Dibrom 8	1 - 3
Parathion	Parathion	1 - 2
Phorate	Thimet 20 G, Rampart 10 G	28 - 84*

* Soil incorporated prior to planting.

may have resulted in larger grasshopper populations in the long run. Continued use of insecticides may result in the development of grasshopper resistance to the products making long term control difficult.

A third method of control is the use of insecticide baits. Insecticide baits have been used in Montana since the early 1900's. Modern baits, which show much promise in grasshopper control, are wheat bran impregnated with a synthetic insecticide, such as Carbaryl. Carbaryl baits have been shown to be quite effective in the control of grasshoppers (Onsager 1980, Johnson 1987).

Insecticide baits are less harmful to the environment than insecticide sprays. They are more selective as the bran must be consumed prior to killing the insect. Baits are safer for aerial application because they are heavier than the small spray droplets and are less likely to drift. The baits

are less likely to lose the insecticide to volatilization. Grasshoppers readily consume the bran baits within hours of application (Mukerji et al. 1981). Less active ingredient per unit areas is used with baits compared to sprays. Finally, baits do not leave a residue on the crop surface as the insecticide adheres to the bran surface.

Disadvantages of insecticide baits include the following. Grasshopper mortality with baits is not quite as high as with sprays. Baits give a mortality of 65% to 75% compared to 95% for sprays. This is primarily because not all grasshoppers are feeding at one time (grasshoppers which are molting are not feeding). Different species of grasshoppers will have different feeding or food preferences and thus may not desire the baits. Presently, the only insecticide bait formulations registered for grasshopper control contain carbaryl as the active ingredient.

The fourth control method currently available to producers is the use of bran bait impregnated with spores of Nosema locustae. Nosema locustae is a naturally occurring protozoan disease of grasshoppers. The use of this disease in the control of grasshoppers was developed at the USDA Rangeland Insect Lab in Bozeman, MT. One pound of wheat bran impregnated with 6 million to 1 billion spores of N. locustae is applied to one acre. Once grasshoppers consume the baits they may become diseased, thus becoming lethargic and unbalanced and may demonstrate slowed development, swollen joints, red discharge from the abdomen, and decreased appetite.

If applied to coincide with the emergence of third and fourth instar nymphs, 50% of the population should die within three to four weeks. Approximately 35% to 50% of the surviving population will also be infected with the diseases and may communicate it to other grasshoppers and grasshopper eggs. Nosema locustae does not give the rapid knock down of grasshoppers that most producers desire during severe grasshopper outbreaks. Though N. locustae takes a few weeks to become effective, it should give long term control (Onsager 1988). Nosema locustae is also host specific. It will attack 58 species of grasshoppers and Mormon crickets but will not affect natural enemies of grasshoppers, pollinators, and other insects and spiders. The disease has no direct effect on fish, birds, or mammals. Infected grasshoppers that do not die will consume less forage (Johnson and Pavlikova 1986).

Nosema locustae, registered as a insecticide bait under FIFRA has several disadvantages. It does not give the rapid knock down or mortality rates of grasshoppers that synthetic insecticides give. Nosema locustae is more expensive than most synthetic insecticides; however, this does not take into account the long term control that N. locustae should give. Under wet weather conditions the baits may deteriorate rapidly.

Another control method which shows some promise is the integration of carbaryl and N. locustae into a bait formulation (Onsager 1981). Onsager et al. (1981) show that combinations of Nosema and Carbaryl baits may allow for quick knock down of grasshoppers along with the long term control of grasshoppers by N. locustae. However, this insecticide bait was not registered for grasshopper control during the control program. An alternative may be to apply a strip of carbaryl bait along side of a strip of N. locustae bait.

Chemical control of insect pests is destined to be a temporary measure (Pepper 1975). Many producers agree with this statement and consider insecticides to be a quick fix to a long term problem. Any year that there is a grasshopper infestation in Montana, millions of dollars go into grasshopper control, only to have to apply controls again the next year if climatic conditions prevail. Spraying adult grasshoppers with synthetic insecticides may give an initial knock down but during infestation years they are frequently replaced by another wave of migrating adults or a hatch of nymphs. This often leads to multiple insecticide applications for grasshopper control in one season which may be prohibitively expensive. Treatment of grasshoppers with non-specific insecticides may lead to the death of beneficial organisms that keep grasshopper populations in check (Pepper 1975, Onsager 1987). Migrating grasshoppers can repopulate treated fields, resulting in population levels similar to those prior to treatment. Beneficial organisms eliminated in a sprayed field may not repopulate the area nearly so rapidly.

History of Infestations in Montana

Grasshoppers have inhabited the great plains in large populations since before recorded history. Lewis and Clark observed grasshoppers in great numbers in Montana in 1805. In 1877 the stream of west bound covered wagons was temporarily halted by swarms of grasshoppers that limited the available forage for the pioneer's animals (Reuter Labs 1989).

Farmers began breaking soil in Montana in the 1880's and by 1909 about 258,000 acres of land were under cultivation. With yields averaging 25 bu/a the amount of wheat and barley cultivated acreage continued to increase to over 3,000,000 acres in just 10 years. During the first 40 years of crop production in Montana, grasshopper outbreaks occurred sporadically throughout the state, in many cases with complete loss of vegetation (Morrill 1983).

Two years of notable outbreaks occurred in 1902 and 1903 (Cooley 1904). A severe drought occurred in 1917-1919, which brought with it the first severe widespread grasshopper outbreak. Migration of grasshoppers was reported to go in a northwesterly direction. Grasshoppers were reported so thick that producers "couldn't see the heads of the wheat". In 1917 yield averages plummeted to 3 bu/a for wheat and barley (Cooley 1918). Producers were even harvesting grasshoppers with an implement termed a "hopperdozer" and feeding the high protein insects to chickens (Cooley 1918). Poor yields began to drive the less tenacious farmers from Montana, which only worsened the situation as grasshoppers were able to lay eggs with high success in the abandoned cropland.

The year 1919 brought severe drought, and the worst outbreaks ever observed occurred in 1920 (Cooley 1921). Species of grasshoppers appeared to change from one year to the next suggesting that host specific parasites may have led to the decline of one species and the increase of another (Morrill 1983). These severe infestations led to the combined efforts of farmers to control grasshoppers. More than 90 farmers from all over the state brought wagon loads of bran, lemons, and oranges to mix with crude arsenic. The poison bran bait was then spread over 200 square miles resulting in the eradication of tremendous numbers of grasshoppers (Morrill 1983). One million acres were treated in 1921 and 1922, at a cost of $280,000. Crop savings were estimated at $3,000,000 (Cooley 1922), a return of $10.70 on the dollar. The outbreak finally ended by 1925. During the next several years Montana had a respite from grasshoppers; however, Mormon crickets became a problem. Mormon cricket infestations peaked in 1927 and then decline to nonexistent levels by 1930, primarily because of natural predation and parasites (Morrill 1983). Parker (1928) noted that two types of wasps in particular were causing a decline in the numbers of crickets.

Populations of grasshoppers remained low in Montanaover the next 8-9 years, while serious outbreaks were occurring in neighboring states in 1931 and 1932. The following year populations began to climb again and by 1934 the migratory grasshopper (Melanoplus sanguinipes) was observed to have egg densities of 600/ft^2 (Strand 1934). Costs of control exceeded monies available in the state and thus the federal government gave financial assistance to help save crops valued at $10,500,000 in 1934-1936 (Strand 1937). During the years of 1936 to 1938 Mormon crickets were also a major problem in Montana, with over 1 million acres experiencing outbreaks each of the three years. Reduced numbers of grasshoppers in 1937 and 1938 were followed by severe migrations of M. sanguinipes from South Dakota in 1939 (Mills 1941). Eastern Montana was hit hardest as grasshopper densities exceeded

500/yd^2. Cool, wet weather in 1942 finally led to a decline in grasshopper populations. Moderate grasshopper outbreaks in 1949 were controlled with synthetic insecticides, such as toxaphene and chlordane (Pepper 1951). This began a new era of grasshopper control, baits coated with crude arsenic, sodium arsenate, or sodium fluoride were now being replaced by highly effective pesticide sprays. Aircraft were adapted for the spraying of insecticides and many believed that the days of widespread insect problems were over. However, grasshopper problems surfaced less than 10 years later. Some of the organochlorine chemicals used at this time were observed to exhibit high toxicity to mammals (including livestock and humans) and to have a long residual effects on the environment. The nonspecific nature of these insecticides were responsible for the destruction of beneficial insects and natural predators of grasshoppers. Unlike baits these insecticide sprays also had the potential of producing genetically immune populations of grasshoppers (Pepper 1975). Pepper, who was the state entomologist at Montana State University, also stated that chemicals are not the long term answer to pest control and that indiscriminate use of insecticides could endanger non-target organisms and result in the removal of many effective insecticides from market. Eventually, all organochlorine compounds would be cancelled or suspended for use in grasshopper control, starting with dieldrin and aldrin in 1974.

Widespread outbreaks of grasshoppers occurred in 1957and 1961 (Pepper 1962), followed by a long period of isolated infestations through the 60's and early 70's. Hot dry conditions in 1974 led to significant infestations in 1975 and 1976 in spite of rather moist conditions in 1975 (NOAA 1975). Many producers desired the return of dieldrin (which had been cancelled in 1974) and financial intervention by the state. However, under Section 18 of FIFRA as amended (CFR 40-166, PL-92-516), no emergency use of insecticides can exist as long as there are effective and sufficient stocks of other registered compounds. Wet conditions in 1978 resulted in low populations of grasshoppers, which would remain relatively low for the next several years.

Chronic hot, dry conditions began in 1983 and the signs of grasshopper problems began to appear in 1984. By 1985 a drought was in progress and with it came a widespread outbreak of grasshoppers. The state reported 15 counties with economically damaging infestations of grasshoppers in the spring of 1985. In response to the extensive losses being incurred by grasshopper damage, the Governor declared a state of emergency and made money available through the Governor's Disaster and Emergency Fund for the control of grasshoppers. Losses caused by drought were so great that damage by grasshoppers was difficult to determine.

A dry spring in 1986 resulted in greater numbers of grasshoppers spread over a greater area. Producers in northeastern Montana reported that grasshoppers were eating the young plants to the ground. Areas not severely affected by grasshoppers or where ample control measures were taken had yields far better than those in 1985, because of a relatively moist summer. Some producers reported complete loss of crops from grasshoppers, while others who achieved effective control had their best yields in 4 years.

Grasshopper infestations were widespread again in 1987 and for a third year the state took part in an emergency cost share program. The hardest hit areas were now farther west. By 1988 grasshopper problems appeared to be declining to isolated infestations in central, southeastern, and southwestern counties. Only a few counties reported emergency situations in 1988. The MDA speculates that this decline in grasshopper infestations was the result of extremely dry weather in 1988. Grasshoppers thrive under hot, dry conditions; however, they also have a requirement for some moisture. The severity of the drought is underscored by the removal of more cattle from the state in 1988 (in response to drought conditions) than any other year in Montana's history. No state assistance for grasshopper control was allocated in 1988.

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CHAPTER THREE

PESTICIDE REGISTRATIONS AND CURRENT INSECT MANAGEMENT PROGRAMS IN MONTANA

The following chapter describes the statutes, rules, andregulations that control pesticide use in the United States and those insect management programs that are available to Montana farmers and ranchers through state, federal, and local government. The purpose of this chapter is to briefly describe the organization, legality, and rationale of the current emergency program. The federal rangeland grasshopper control program is authorized and conducted by the USDA-APHIS. The state cropland emergency grasshopper program is authorized through the Governor's office and specific portions of the program are allocated to the MDA, the Montana Department of Military Affairs, and the participating county governments.

Pesticide Registration Procedures

The Montana Pesticides Act requires the MDA to register any pesticide that is federally registered by the Environmental Protection Agency (EPA) if a chemical company requests registration in Montana and meets other registration requirements of the act (80-8-201(1), MCA). The company must submit each calender year: their name and address; the pesticide name; a copy of the label; and a $50.00 registration fee. Under the Montana Pesticides Act (MPA) the State of Montana has the authority to cancel, suspend, or further restrict a federally registered pesticide product in addition to the EPA's restrictions.

All pesticides that are sold in the U.S. must be registeredby EPA (7 USC 136a). The federal registration requirements are listed in 40 CFR, Part 158. Registration data requirements include product chemistry, product composition, physical and chemical characteristics, residue chemistry, setting of food tolerances, environmental fate, hazard to humans and domestic animals, reentry protection, pesticide spray drift evaluation, hazard to nontarget organisms, and product performance (40 CFR, 158.100 - 158.170). Courts have uniformly held that EPA actions under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, are exempt from EIS requirements under the National Environmental Protection Act (NEPA). Data generation for registration of new pesticides typically takes several years and may cost $5 - $8 million or more.

Some pesticides with federal registration do not meet thecurrent EPA requirements to support registration. The EPA is currently conducting a re-registration review to identify data gaps and give registrants an opportunity to conduct studies to provide the missing data. During the re-registration process, the EPA reviews all available data for a particular pesticide and identifies studies that are missing or inadequate. A re-registration standard is then issued notifying registrants of the data gaps identified and the timetable for completing the necessary studies. Specific actions including labeling changes, restricted use classification, formulation changes, etc. may be required to insure that no unreasonable adverse effects to humans or the environment will result from continued use. The re-registration process has been completed for 149 of over 600 pesticide active ingredients registered, and another 34 re-registration standards are under development. If registrants do not meet requirements for missing data, product registrations will be cancelled by the EPA.

The data call-in provisions of FIFRA allow the EPA toobtain additional data to support registration (7 USC 136a(2)(13)). Registrants must also notify EPA if they have additional data regarding potential unreasonable adverse effects of a pesticide (7 USC 136d(a)(2)).

The EPA may also initiate a Special Review of a pesticide that may cause unreasonable adverse effects on humans or the environment (40 CFR Part 154). The Special Review process is a comprehensive analysis comparing the risks and benefits of pesticide use. It is triggered by evidence of serious acute injury, substantial chronic or delayed toxic effects, harmful levels of pesticide residues in the environment, jeopardy to threatened or endangered species, destruction of critical habitat, or other significant risks to humans or the environment (40 CFR 154.7). If the EPA determines that the risks of pesticide exposure outweigh the

benefits of continued use, the pesticide may be suspended, cancelled, or reclassified as restricted-use.

Both the re-registration process and Special Reviews are open to public participation. Public dockets are established and opportunities for comment are provided.

Labeling, Classification, Licensing

Pesticide labeling is approved by the EPA during the registration process. It provides detailed instructions for the correct and proper use of a pesticide including acceptable crops or sites, safety precautions, environmental precautions, storage and disposal instructions, mixing directions, and application rates. Labeling requirements are described in detail in Title 40 of the Code of Federal Regulations (CFR) section 162.10 and 4.10.705 - 707, Administrative Rules of Montana (ARM).

All pesticides sold in the U.S. must have approved labeling (7 United States Codes (USC) 136j(1), 7 USC 136(q)), and a pesticide may not be used in a manner inconsistent with its labeling (7 USC 136j(2)(G)). Similarly, all pesticides used in Montana must have an appropriate, complete, and legible label and cannot be applied in a manner inconsistent with the label (80-8-305(1)MCA). Therefore, the pesticide labeling is a legally enforceable document as well as a source of valuable information concerning use of the pesticide.

Pesticides are classified by the EPA or the state as generaluse or restricted use. General use products should not cause unreasonable adverse effects to the environment when used according to labeling directions and precautions or according to widespread and commonly recognized practices (7 USC 136a(d)(1)(B)). When making this determination, EPA considers the economic, social, and environmental costs and benefits of labeled pesticide use (7 USC 136(bb)). This means that any risks to human health, fish and wildlife, water quality, and other environmental factors must be weighed against the benefits of pesticide use before it can be registered. If applicators read and follow labeling directions, the risks to humans and the environment and cumulative environmental impacts will be minimized.

Some pesticides are classified as restricted-use and canonly be used by certified applicators or persons under their direct supervision (7 USC 136j(a)(2)(f), 7 USC 136a(d), 40 CFR 162.10(j)(2), 4.10.707(b), ARM and 4.10.708, ARM). The criteria for classifying a pesticide as restricted use are described in 40 CFR 162.11, MCA 88-8-101(34), and 4.10.703, ARM.

The FIFRA and the MPA both require that commercial, government, public utility, and private (farm) applicators who desire to use restricted use pesticides be certified. To become a certified commercial or government applicator, individuals must pass a basic pesticide examination and a specific examination for a particular applicator classification with a score of 80 percent or better (4.10.203(3)(b), ARM. Training sessions, which are not mandatory are provided by the MDA and the Montana State University Extension Service (MSUES) for commercial and private applicators respectively. These sessions are designed to provide information to assist the prospective applicators in learning the information required to pass the exams. Once certified the applicators must attend training sessions (or be re-examined) on a periodic basis to maintain the certification. Commercial and government applicators are required to be recertified every fourth year and private applicators every fifth year.

Training sessions for each individual category are offeredon a four year rotating schedule with two six hour courses offered every four years. A number of industry sponsored training sessions (approved by the MDA) are generally offered each year. The training for all applicators provided over the recertification period must provide information on the following subjects: laws and regulations, equipment, calibration, safety, pest identification, pesticides, disposal, first aid, groundwater, endangered species, and other environmental concerns. Information on specific pests, such as grasshoppers is an integral part of these training sessions

To apply general use pesticides; commercial, public utility, and government applicators must pass the test with a score of 70% or better. Applicator classifications are described in 4.10.202, ARM, and the standards for competency are listed in 4.10.203, ARM. Applicator certification procedures help reduce the risk of using restricted-use pesticides that may be more hazardous to humans and the environment than general use pesticides. Farm applicators may become certified either by attending an approved training course and taking a quiz or by passing an examination with a score of 70% or better. Farm applicator certification is discussed in MPA (4.10.401 ARM) and additional standards for competency are described in 40 CFR 171.5. Private applicators are required to recertify once every fifth year.

USDA-APHIS Rangeland Grasshopper Control Program

In 1934, a year of particularly devastating grasshopperinfestations, Congress recognized that the problem was beyond the ability of the individual or community organizations to combat, and charged the United States Department of Agriculture with assisting in grasshopper control efforts. Each year, since 1934, the USDA has worked with state agencies and private landowners to assist with grasshopper control on public as well as private lands whenever economic infestations have occurred.

The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) assists the affected states and farmers/ranchers with rangeland grasshopper control on private lands that meet the federal program requirements.

The major program conducted by APHIS is the rangeland "block" treatment program. There are several criteria for this program which includes:

-- blocks of rangeland of at least 10,000 contiguous acres, or an area that totally encompasses an infestation.
-- no more than 20% total cropland (including fallow land) within the 10,000 acre block.

-- an economic infestation (at least 8 adults or an equivalent number of immature grasshoppers per square yard).

-- treatment application before the majority of grasshoppers reach maturity and egg laying has begun.

In most states this program is cost-shared on a 1/3 basis.The federal government pays 1/3, the state pays 1/3, and the producer pays the remaining 1/3. The state of Montana has never cost-shared in this program, which means the producer pays 2/3 if he wants to participate. This has been a source of frustration to many producers over the years. When this program was initiated the 10,000 acre block idea probably made sense. However, today in most areas of Montana, finding 10,000 acre blocks of rangeland with only 20% cropland is difficult. The Montana Department of Agriculture has tried for years to get APHIS to either reduce the size of the blocks or increase the percentage of cropland, but has been unsuccessful. Though this program is available to

producers in Montana, it is unworkable in many areas of the state. Another criticism of this program has been that treatment occurs too late, i.e. there are too many adult grasshoppers in the population being treated.

In the past several years, APHIS has introduced what it calls the cropland protection program and the criteria for this program includes (USDA-APHIS 1987):

-- economic grasshopper infestations or the presence of threatening migrating populations in the immediate area.

-- susceptible crops growing adjacent to federal rangeland.

-- removal or protection of honey bees and pollinating bees by owners so that timely treatments may be applied.

The treatment of federal rangeland for cropland protection generally consists of spraying a 1/4 to 1/2 mile strip of adjacent rangeland. Other categories of rangeland ownership (private, state) will be treated if they meet the above criteria and are contiguous with federal rangeland being treated.

This type of program makes sense in Montana. Unfortunately it has not been a widely publicized program in Montana and not many producers have taken advantage of it. But here again the producer must pay 2/3 of the cost. Another requirement that is somewhat undesirable is if a producer wants to participate he must put his money up front (like an escrow account) usually several months before the grasshopper season. Cash outlays for most producers occur during the spring (seeds, fertilizers, herbicides, fuel) and this is an added expense he may not be able to afford.

In 1950, a state/federal task force studying grasshoppercontrol recommended that the federal government drop its involvement with grasshopper control on cropland. The task force reasoned that the then - newly developed, relatively inexpensive, effective chemicals - made it possible for growers to control grasshoppers on their own, or with only periodic state assistance.

APHIS also claims that the insecticides used in the large-scale rangeland programs are not as effective in killing grasshoppers on crops at the application rates recommended for rangeland. This reduction in effectiveness is due, in part, to the density of crop foliage. Also, label restrictions do not allow application of some of the insecticides used in

rangeland grasshopper control to all crops. Thus, since 1950, the APHIS program has not been involved in cropland grasshopper control in Montana.

It is still generally agreed that most grasshopper eggs arelaid in undisturbed sites such as provided by native range and pasture. If they are not treated here, they move on in search of more succulent vegetation as the range grasses dry out. Eventually they end up in cropland and, depending on population numbers, this is where the most significant economic damage can occur. Most producers realize this and if they cannot afford to protect their rangeland resources the battle lines become drawn at the crop borders. While this is not justification for a cropland grasshopper control program, it occurs to a greater or lesser degree (depending on grasshopper numbers) every summer in Montana.

The Emergency Grasshopper Control Program

The Montana Department of Agriculture under the authority of the Crop Insect Detection and Management Act (Title 80, Chapter 7, Part 5, (MCA)) is responsible for monitoring insect populations and determining whether the populations are normal or are high enough to constitute a threat to agricultural crops. Insect pests that are economically damaging to agriculture typically are present from spring to early fall, thus field monitoring would occur during this time period.

There are a number of insects that, under proper climaticconditions, have the potential to cause serious economic damage to a variety of crops in Montana. In recent years, however, cutworms and grasshoppers have dominated as the species causing the most widespread problems in the state. In 1988 the Russian wheat aphid emerged as a problem pest that can cause as much economic damage as each of the other two insects mentioned.

In the spring of 1985 grasshoppers emerged as the insectpest of greatest concern. The Department started receiving calls in early May (which is a month earlier than most years) about the large numbers of small grasshoppers that were being seen in range and pastureland. The entomologist and several of the seasonal biological aids (field scouts) began making grasshopper counts to determine the level of infestation. The Department uses the economic threshold as determined by the USDA, i.e., 8-9 adult grasshoppers per square yard or 24-27 nymphs per square yard up to the third instar of development(USDA-APHIS undated). Data gathered by the Department and county extension agents

indicated grasshopper infestations to be at or near the economic thresholds in 15 counties.

On June 11, 1985 Governor Schwinden issued a Proclama-tion of Emergency under Title 10, Chapter 3 (MCA) (Appendix C) concerning the grasshopper infestation and the implementation of an emergency program in cooperation with the counties and the agricultural producers. The Department of Agriculture passed emergency rules implementing the mechanism for the equitable distribution of funds to counties that participated in the program (Appendix C). The Disaster and Emergency Service Division, Department of Military Affairs, sent informational packets to the counties on how to become a participant in the program.

To participate in the program, the counties were requiredto levy an emergency 2 mill levy for grasshopper control. Since the Emergency Proclamation was in affect for only 20 days the counties had to move quickly to inform county residents if they wished to enter the emergency program. Counties participating in the program issued an emergency proclamation under the authority of 10-3-405 (MCA) (Appendix C) and transmitted the proclamation to the Department of Military Affairs, Disaster and Emergency Services Division.

Once the county proclamation had been received and approved, the county entered into a pest management agreement with the Montana Department of Agriculture. Prior to signing the agreement, the department had to determine that a serious grasshopper infestation existed in that county. Both parties(Department-county) signed this agreement (Appendix C).

The county informed the landowners that the programwas in effect. The landowners made commitments to the program during the 20 days that the proclamation was in effect. This commitment was made in one of several ways:

1) They (the landowners) could purchase pesticides or contract to purchase pesticides during the 20 day proclamation period.

2) They (the landowners) could contract with a commercial pesticide applicator to have their cropland treated prior to the end of the 20 day proclamation period.

3) The actual application of the pesticides, whether done by landowners or by a commercial applicator, must be done within 10 days of the last day of the 20 day proclamation period.

The dated, paid bills for the pesticides and/or services were proof of participation by landowners. The dated, paid bills were submitted to the county by a date specified in the Department's emergency rules for partial reimbursement with county and state funds.

The emergency program permitted the landowners to useany pesticide, including biologicals, which were registered in Montana for grasshopper control for that year (Appendix A). This requirement was established by emergency rules promulgated by the Department.

Title 80, Chapter 7, Part 5, MCA, provides a mechanismfor the distribution of funds to counties who participated in the emergency grasshopper program. State participation was limited to the funds established in the Governor's Emergency Proclamation and the state/county agreements. State participation was limited to a maximum expenditure per acre (e.g. $1.25/acre), or no more than 1/3 of the cost of the program, or a pro rata distribution based on the total statewide program costs compared to each county's program costs. The upper limits of the state's participation is established by 80-7-504, MCA.

Related Departmental Programs

When the department employed biological aides (scouts)to monitor pest populations, they also provided specific information to producers on grasshopper dynamics and current control methods. The entomologist frequently held producer meetings in affected counties in the spring. These meetings were used as a forum through which producers could gain information on the available grasshopper control techniques and current population projections.

The USDA-APHIS personnel also met with producergroups in the early spring to inform producers of their fall egg counts and where projected grasshopper problems might occur. This coupled with the information from the MDA helped the producer identify the likelihood of a grasshopper outbreak in their area and how they might approach controlling the problem.

When the department hired biological aides prior to 1986, they provided this kind of information on a one-to-one basis during their weekly travels. For general insect, disease, weed, and rodent monitoring, scouts are the department's, as well as the producer's, eyes and ears. Without scouts, daily pest population counts are difficult to obtain. Scouts may not prevent an emergency situation from occurring; however, the first hand data that they collect may result in early diagnosis and treatment of a problem that otherwise may reach extreme levels.

Education of producers and applicators occurs annually through pesticide certification and recertification workshops sponsored by the department, the MSUES, and the county extension agents. The workshops provide general information on application techniques, currently registered pesticides, and integrated pest management. The MSUES and the MDA have been, or are currently, involved in IPM programs which serve to educate and implement an integrated approach to pest management. The MSUES small grains pest management program remains a pilot program and the MDA was forced to abandon it's IPM programs because of lack of funding and limited staff.

The response of the farm and ranch community to thegrasshopper outbreaks of 1985, 1986, and 1987 was based on individual decisions on how they best felt they could deal with the situation. The Governor's office, MDA and Department of Military Affairs reacted in the only way they are allowed by state law. If producers and counties wished to participate in the State emergency program, they were required to meet the set qualifications. The choice of how they might manage the grasshopper program on their land was their decision and was not dictated by the state.

Results of the Emergency Program

In 1985 numerous counties made inquiries concerningthe program; however, due to program restrictions (mainly the time factor), money limitations, and the drought many counties decided not to participate. Ten counties initiated the process to join the emergency program. Glacier County did not levy the 2 mill emergency levy, and hence did not qualify. Fallon County implemented the 2 mill levy, however, their program included rangeland and the state program specifically excluded rangeland.

In 1985, the following counties met all the criteria: Carter, Judith Basin, Pondera, Prairie, Sheridan, Wibaux, Stillwater and Wheatland. Neither Stillwater or Wheatland counties submitted claims apparently because of lack of participation by producers.

In the six counties participating in the program, 661 producers treated 226,418 acres at a cost of $804,270.15. The combined 2 mill levy in these counties raised $310,154.82. The state, through the disaster and emergency funds utilizing the formula established by state law and the emergency rules, participated in the amount of $215,395.31. The farmers actual costs thus amounted to $278,720.02.

The 1985 state emergency program covered about 225,000 acres of crop land (approximately 2.4% of cropland in Montana). Producers received a average of $0.99 per acre from the state and $1.37 per acre from the county for an average insecticide cost of $3.55 per acre.

The state received some moisture in the fall of 1985 andsome sections of the state received spotty amounts of precipitation in the spring of 1986. It was hoped that maybe the drought cycle was beginning to break. This was not to be. In late May and early June, calls began flooding the Department reporting high numbers of grasshoppers, particularly in northeastern and southeastern Montana. To meet the requested 5% budget reduction for FY'87, the Department had committed to not hiring any seasonal help (biological aides) during the summer of 1986. This meant that the only person the Department had to verify grasshopper numbers in the counties was the entomologist. Reports of severe grasshopper damage were received from over 25 counties. Obviously one person could not adequately check this many counties in a short time span and make an accurate determination of grasshopper numbers. So the MDA quickly trained several of its field employees (pesticide specialists) and sent them into what appeared to be the hardest hit counties to make grasshopper counts. Also the department elicited help from some of the county extension agents who had entomological training and additionally received some help from the USDA/APHIS rangeland grasshopper scouts. Grasshopper counts and damage reports from approximately 15 counties were made available to the Governor's office in mid-June.

As a result, Governor Schwinden issued a Proclamationof Emergency on June 20, 1986. The program criteria for county and producer participation were the same as those identified for the 1985 emergency grasshopper program.

Twelve counties initially levied the 2 mill emergency levyand signed the crop insect management agreement with the Department. Eventually, three counties decided not to participate. The remaining nine counties that qualified to participate were: Carter, Daniels, Golden Valley, Petroleum, Richland, Roosevelt, Sheridan, Treasure and Wibaux.

Claims from the nine counties indicated that 1,246 producers treated 721,318 acres at a cost of $2,333,101. This was more than triple the amounts reported for the 1985 emergency program. The state's participation in 1986 was $350,000.

Producers received an average of $0.48 per acre from the state and $0.90 per acre from the county in a year when the average bill for one application of insecticide was about $3.50 per acre. In Sheridan County many producers felt positive about the program and suggested that it gave

them incentive to control grasshoppers even though they were only receiving $0.41 per acre from the state.

Gordon Stoner, a producer in Sheridan County claimedthat grasshoppers were in such great numbers and were devouring the crop with such rapidity that he considered just claiming a complete loss. With the announcement of the state program he decided to spray his crops. Mr. Stoner's yields were about 28 bu/a. He suggested that without control his yields might have been reduced by about a third. Durham wheat priced at $4.00/a for 2,500 acres saved this one producer $93,000 in yields. If this producer paid taxes in a 5% tax bracket, the state would have earned $4,667 from the $1,025 given to Mr. Stoner.

Terry Angevick (1988), the Extension county agent for Sheridan County, suggested that losses due to grasshoppers in Sheridan county in 1986 were a minimum of 30% on lands where no control measures were taken. This is equivelent to a loss of gross cash receipts for the state of $14,887,096.00 for Sheridan County alone (based on the number of acres in the program in Sheridan County, a 5 year yield average for wheat in Sheridan County, and a 5 year wheat price per bushel average for the state). However, because grasshopper control generally required more than one treatment per growing season and 100 percent control under any one treatment was probably not achieved, this can not be considered as a linear relationship.

Many producers and extension agents from counties,other than Sheridan County, that took part in the cost share program agreed that the amount of money they received was insignificant compared to their total control bill. Producers in Daniels County in 1986 received $0.36 per acre from the state and $0.18 per acre from the county on an average chemical cost of $2.59/a. The emergency program was funded for a single treatment during a 20 day period. Since many producers sprayed their field 3 to 5 times they received $0.54 per acre on total treatment costs of $7.77 per acre to $12.95 per acre (4.2 to 7.0% of the total spray bill).

During the 1986 program, more than 40,000 acres were treated with Nosema locustae. Unfortunately, it appeared that the sheer numbers of grasshoppers and their movement into and out of the Nosema treated areas, simply overwhelmed the ability of the Nosema to take its toll on the grasshopper population in that area. We have since learned that Nosema should probably not be recommended for use during outbreak years unless applied when the majority of grasshoppers are still 3rd instar or younger.

The 1986 program also reminded us of a harsh biologicalfact that adult (or near adult) grasshoppers are very hard to kill, regardless of the pesticide used. Grasshoppers can generally be controlled when they are in the first, second and third instars; however, control diminishes rapidly

when they reach the fourth and fifth instar stage. Much of the treatment during the 1986 program occurred after July 1, when the ratio of young to old grasshoppers was probably close to 50:50. The point being made is that if, in 1986, the grasshoppers had been treated earlier there would have been fewer eggs laid and just possibly fewer grasshoppers hatching in the spring of 1987.

It became evident early in 1987 that portions of Montana were still in the drought cycle. Based on historical data and experience of Department personnel, we did not believe 1987 would be a year with significant grasshopper problems. However, a mild winter and spring probably resulted in a higher than average overwintering of grasshopper eggs and nymphs. In any event, the Department entomologist confirmed the presence of numerous nymphs in several northeastern counties in early May.

To prevent the situation that occurred in 1986, the Department contacted the Governor's office in mid-May. After receiving additional data, Governor Schwinden issued an Emergency Proclamation on June 1, 1987.

Initially, there were eight counties that levied the 2 millsand signed the management agreement. Three counties elected not to participate which left the following five: Daniels, Petroleum, Sheridan, Treasure, and Yellowstone.

Claims for the five counties indicated that 667 producers treated 334,573 acres at a cost of $1,241,943.62. The emergency rules established that the state's participation in the program would be up to 1/3 of the total cost of the qualified acres per county, not to exceed $1.25 per acre and also not to exceed $200,000 or the unobligated balance as of June 30, 1987, whichever was less. The unobligated balance as of June 30, 1987 was $175,000 which became the state's share of the program.

There are a number of problems and inequities with thestate emergency grasshopper program. Grasshopper infestations in 1985, 1986, and 1987, were fairly widespread in eastern Montana; however, only 5 to 9 counties ever participated in the program in any one year. Many counties did not participate in the program because they could not afford to levy the necessary 2 mills to enter the program. In one case a county had already levied monies for a flood emergency relief program and thus could not afford to enter a second emergency program.
Non-participation by a county might be due to lack of money available or to lack of interest within the county. The program did not provide equitable financial assistance for producers across the state. In some cases a county line might delineate whether a producer would be eligible

for state assistance. Obviously grasshoppers have no concept of a county line and infestations do not end at these lines.

Another source of discontent was that during the years ofgrasshopper infestations other severe insect outbreaks were also occurring. For example, an isolated sawfly outbreak in Liberty County may have been at least as economically damaging as a site of a moderate grasshopper infestation in Sheridan County; however, only grasshopper control was funded by the state.

The enormity of production costs for small grains in Montana with or without insecticide costs greatly dwarfs the state expenditures for the grasshopper emergency program. The expenditure of emergency funds compared to the amount of money that the state receives annually from farm production is quite small. For example, in 1987 13% of the state's income ($204,345,000.00) came from wheat and barley production alone.

Some producers feel that the state emergency programgave them incentive to spray or spread baits while the majority suggested that they would have controlled grasshoppers with or without the program. Whether this program actually increased the total amount of insecticides used is difficult to determine.

An estimated value of 11,321 gallons of liquid insecticides may have been used in the program based on the number of acres covered and an average treatment rate of 8 ounces per acre (14.4% of total liquid insecticides sold in Montana in 1985). By far, the majority of insecticide use in the program would have been liquid insecticides. The amount of liquid insecticides sold in Montana increased from 47,158.5 gallons in 1983 to 78,547.75 gallons in 1985. This 30,000 gallon increase in liquid insecticide sales is most likely a response to the severe grasshopper infestation in 1985.

Though liquid insecticide sales increased by more than30,000 gallons between 1983 and 1985, the amount of dry insecticides sold during this period decreased by more than 200,000 lbs. This decrease is a reflection of change in insect problems. The primary insect pests in 1983 were cut worm, army worm, and wire worm. The various insecticides differ in specific gravity and thus calculating the total amount of insecticide use in pounds is impossible. If we were to estimate a specific gravity of 10 lbs/gallon (carbofuran for example is 11 lbs/gallon) the total insecticide use in the state would have increased by more than 100,000 lbs between 1983 and 1985. The state program accounted for an estimated 11,321 gallons of liquid insecticides sold in 1985, this would be approximately 8.8% of the total insecticide sales in Montana in 1985.

Pesticide sales in Montana are tabulated once every 5years for that particular year. Since 1985 was the last year of such tabulation, there is

no way to accurately determine the incremental increase in insecticide use in Montana in 1986 or 1987.

Years of drought frequently coincide with grasshopper outbreaks. Drought and grasshopper infestations in 1985 reduced state cash receipts for wheat and barley from a five year average (1980-1984) of $658 million down to $311 million (USDA/MDA 1987). This is an 8% decline in Montana's total cash receipts. The severity of the 1985 drought makes determining the amount of damage done by grasshoppers a difficult task; however, many producers felt that without controlling grasshoppers in 1985 crop damage would have been extremely high.

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CHAPTER FOUR

THE AFFECTED ENVIRONMENT

Introduction

Grasshoppers and Mormon crickets have caused extensive economic damage to cropland and rangeland in Montana. Grasshoppers maintain the potential for such agricultural damage in spite of the years of research and development that have gone into the control of these insect pests. Cropland, rangeland, neighboring wildlife habitat, and recreational lands are directly and indirectly affected by grasshopper outbreaks and grasshopper control measures. The state grasshopper emergency program provided financial assistance for grasshopper control in cropland in a total of 14 counties over a three year period (Figure 1).

The following chapter describes the natural and agricultural environment that is potentially affected by severe grasshopper outbreaks and the actions implemented under the state grasshopper emergency program to control the outbreaks. This chapter is broken down into three sections; crop production in Montana, the affected environment for Montana, and a more detailed discussion of four separate regions of Montana. These four regions are separated by their climatic and geographic differences (Figure 2). The affected environment includes a discussion of the topography and climate, geology and soils, vegetation, terrestrial wildlife, water resources, air quality, human populations, and cultural resources.

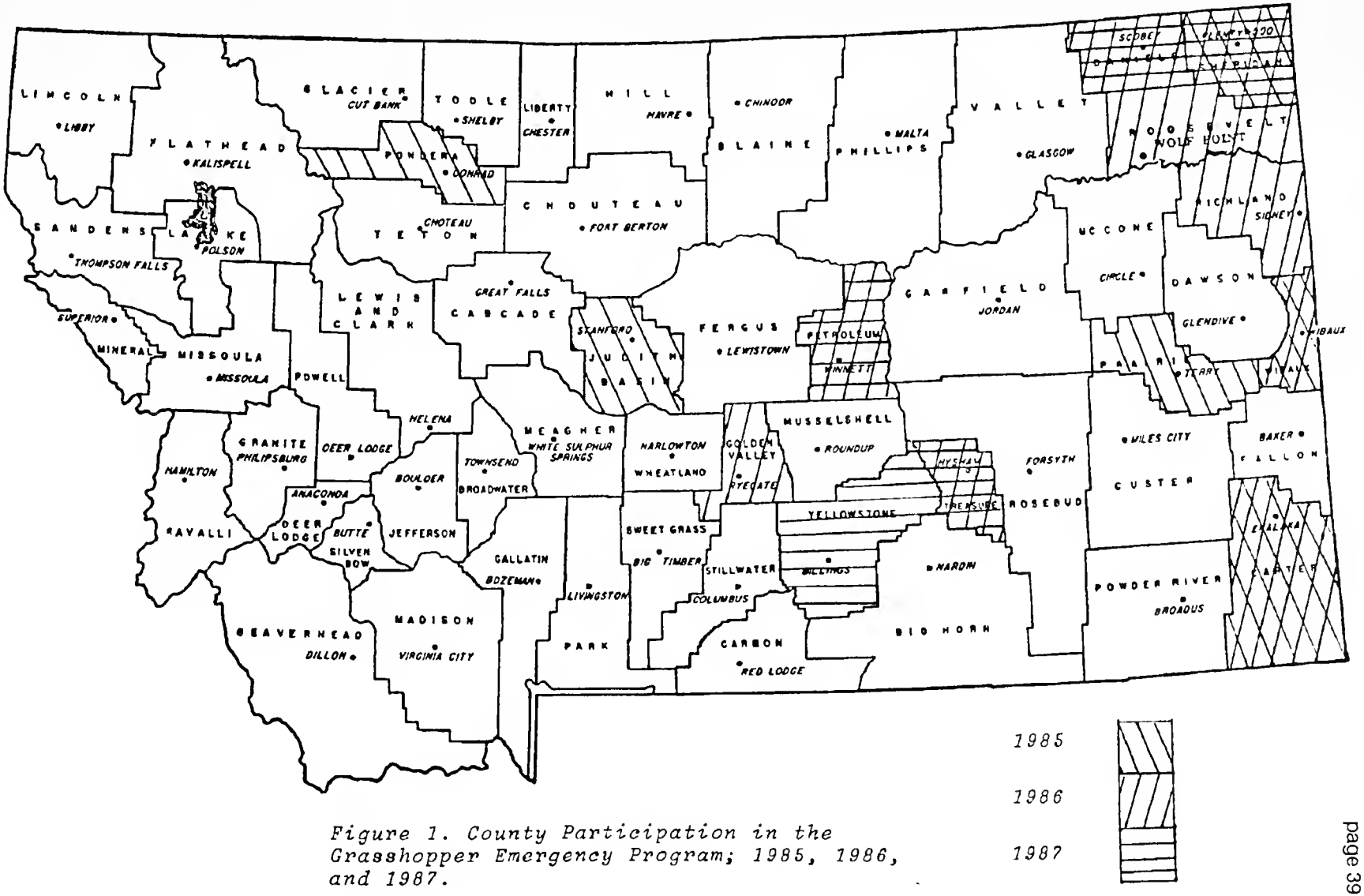

Figure 1. County Participation in the Grasshopper Emergency Program; 1985, 1986, and 1987.

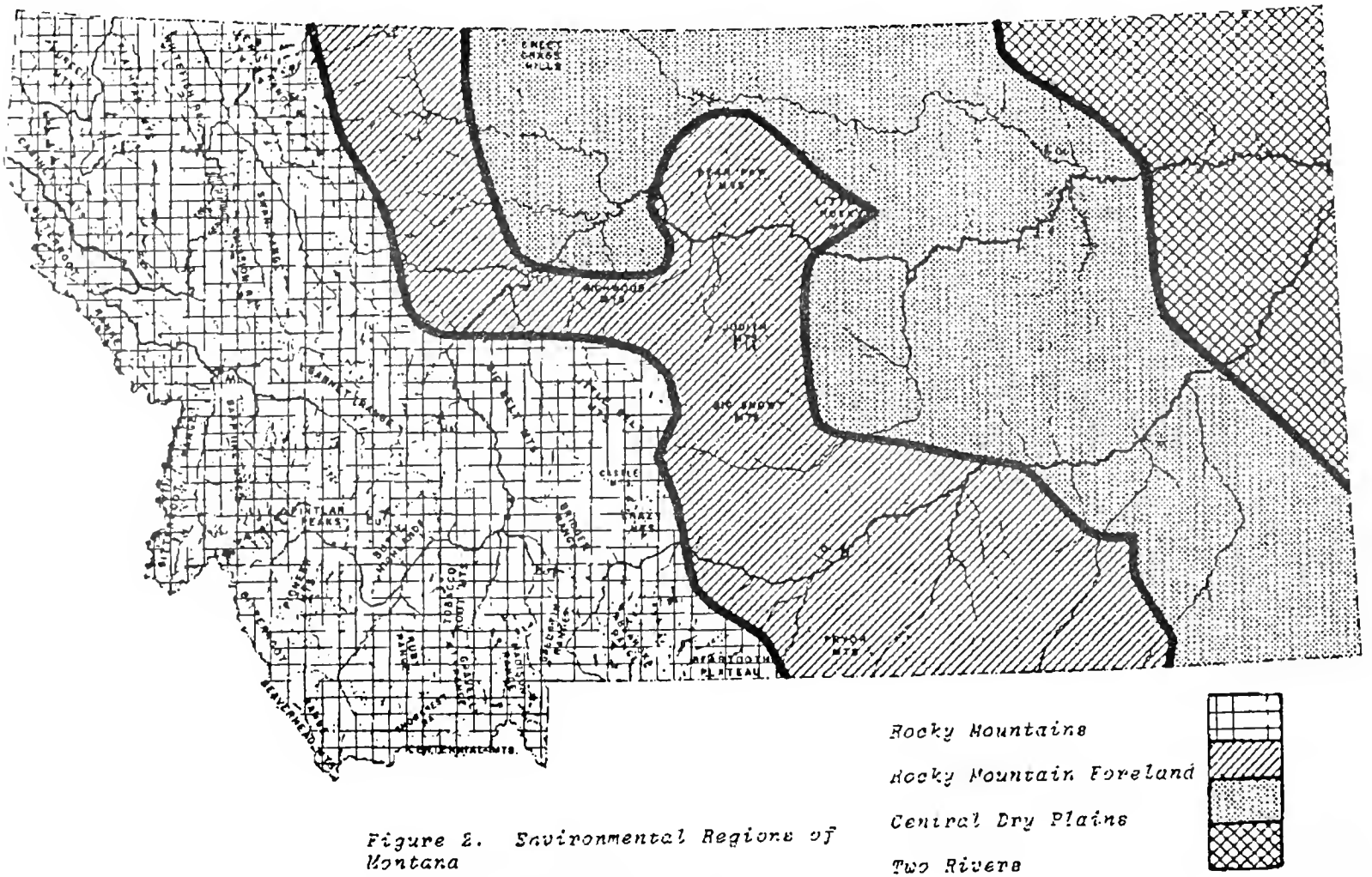

Figure 2. Environmental Regions of Montana

Adapted from the EQC (1972)

Crop Production in Montana

Crop production accounts for about half of the state's agricultural receipts, the vast majority of which is wheat and barley (MDA/USDA 1988). In 1987 Montana ranked 3rd in wheat production in the nation producing 151,220,000 bushels (MDA/USDA 1988). Wheat production in Montana consists of three broad types; winter wheat, spring wheat, and durham wheat. The majority of spring and durham wheat produced in the state comes from the northern counties east of the continental divide while winter wheat is produced throughout the eastern two thirds of the state.

Montana ranked 3rd in the nation for barley production in 1987 producing over 94 million bushels of grain (MDA/USDA 1988). Barley is produced throughout the state as a cash crop for malting or as a feed crop for cattle. Other agronomic crops produced in Montana include sugar beets and corn (produced along the lower Yellowstone and Missouri river valleys), potatoes (produced primarily in Gallatin, Lake, and Flathead counties), hay (produced throughout the state), oats (produced primarily in the north), and oil seed crops (produced primarily in north central Montana, the triangle region).

Total cash income in Montana is primarily generated by agriculture (crop and livestock production). In 1987 agriculture accounted for approximately 38% of Montana's income. Lumber ranked 2nd in Montana (20%), tourism 3rd (19%), mining is 4th (13%), and gas and oil 5th at (10%) (MDA/USDA 1988). The effect of grain crop production on Montana's business activity can be estimated by a Type II Input-Output multiplier. A 1986 estimate suggests that for every $1000.00 of revenue from wheat sales, an additional $1,840.00 of business activity could be generated in Montana (Brester et al. 1986).

Greater than 90% of crop production receipts in Montanais attributable to wheat and barley. The majority of this grain production is non-irrigated "dryland farming". The majority of the dryland acres are produced under a crop-fallow system to conserve soil moisture during the fallow year. Crops grown under crop-fallow will generally yield 4 - 5 bushels per acre more than continuous cropped dryland acreage.

The high investment costs and moderate returns of growing grains have recently resulted in narrow, marginal returns. This is exemplified by the Enterprise cost figures (Table 3) prepared for Montana in 1983 by the USDA (1983, 1985). The figures indicate that cash flow for wheat and barley production in Montana can be negative. For example the given production costs for spring wheat following fallow are $112.27. The 1987 value of spring wheat per acre was $78.30; this indicates a loss of $33.97

Table 3. USDA Enterprise cost figures for dryland wheat and barley following fallow.

Crop/Variable	Value or Cost/acre (dollars)	Cost/Unit Production (dollars)
Barley		
Pre-harvest Costs	37.25	1.00
Harvest Costs	8.40	0.23
Capital Costs	33.46	0.90
Rent and Farm Overhead	33.43	0.90
Total Costs	112.54	3.03
Cash Receipts 1983	86.01	
Cash Receipts 1987	83.25*	
Net Return 1983	-26.53	
Net Return 1987	-29.29	
Hard Red Winter Wheat		
Pre-harvest Costs	48.99	1.49
Harvest Costs	7.56	0.23
Capital Costs	36.03	1.10
Rent and Overhead	45.16	1.38
Total Costs	137.74	4.20
Cash Receipts 1983	122.05	
Cash Receipts 1987	93.60*	
Net Returns 1983	-15.69	
Net Returns 1987	-44.14	
Hard Red Spring Wheat		
Pre-harvest Costs	35.24	1.39
Harvest Costs	6.01	0.24
Capital Costs	31.95	1.26
Rent and Overhead	39.06	1.54
Total Costs	112.27	4.44
Cash Receipts 1983	97.38	
Cash Receipts 1987	78.30*	
Net Returns 1983	-14.89	
Net Returns 1987	-33.97	

Source: USDA (1983)

* Value taken from MDA/USDA (1988). All winter wheat and spring wheat, does not include value of straw.

per acre in 1987 and losses in 1985 would have been $72.43 per acre. This is not the case for each individual producer, but is based on average costs of crop production and does not account for government or insurance payments (Appendix D complete figures).

With the exception of hard red spring wheat, none of the figures specifically takes into account the use of insecticides. Insecticide use is generally considered a minor portion of small grain production costs in Montana.

Most of the communities of eastern Montana are dependent on agriculture to sustain an economic and social base. Natural disasters which reduce the productivity of Montana's grain industry has a proportional effect on rural and urban centers of Montana.

A form of agriculture which is adversely affected by pesticide use is organic farming. Organic farming can be defined as crop production without the use of synthetic agricultural chemicals. Though many of the same crops are grown organically as those grown by conventional methods, organic produce generally brings a higher price than non-organic produce. Certified organic wheat brings a premium price of 20-30% over market price (Quinn 1988). The value of organic produce can be lost if the crop is contaminated by synthetic insecticide residues. Disease and insect problems in some areas of Montana, as compared to many other wheat producing states, are relatively low. These portions of the state would be well suited for organic wheat production.

Topography and Climate

There are over 93 million acres of land in Montana, typified by mountains, plains, broad river valleys, and exceptionally diverse climatic regimes. The eastern 2/3 of the state is characterized by rolling mid-grass prairies divided by valleys of major waterways and ephemeral streams. Small isolated mountain ranges and the forelands of the rocky mountains occur within this area.

Elevation ranges from less than 2,000 ft in the east to 4,000 ft in the rocky mountain forelands. The western 1/3 of the state is separated from the plains by the front range of the rocky mountains which runs in a southeast-northwest direction. Elevation in the mountainous regions varies from 2,300 ft, where the Clark's Fork leaves Montana, to over 12,000 ft in the southern mountains. The climate is also extremely variable. Average annual precipitation ranges between extremes of 4

in/year to 140 in/year. The general region falls under continental climate, semi-arid in nature, averaging between 11 inches and 17 inches of precipitation annually.

Geology and Soils

Bedrock geology of Montana is comprised primarily of precambrian age metamorphic rock in mountain cores with fine grained metamorphic rock overlying this basement complex. Igneous rocks of the Idaho and Boulder batholiths are somewhat localized in the western mountains. Volcanic bedrock is found in southwestern and north central Montana. Sedimentary rocks of sandstone, siltstone, shales, limestone, and dolomite make up most of the strata of the plains regions.

Continental glaciers covered the northern portion of thestate leaving behind a glacial topography of moraines, lakes, lake deposits, till, and outwash. Northwestern and southern mountains retain alpine glaciers. Mountainous regions have historically received large quantities of volcanic ash from Washington and Oregon and much of Montana has been laden with loessal deposits at some point in history (Montagne 1983).

Soils form in the surface mantle which overlies bedrock. Time, topography, climate, biological activity, and parent material are the five factors which determine the physical and chemical characteristics of a soil. Parent material is primarily mineral matter which either weathers in place (residuum), or is the product of deposition by glaciers, water (alluvium), gravity (colluvium), or wind (eolian). Soils of Montana reflect the extreme heterogeneity of Montana's geologic history, topography, and climate. Chemical properties of a soil are primarily dictated by the composition of the parent material.

Five primary soil orders are found in Montana and are illustrated on a general soil map adapted from the USDA-SCS (1978) (Figure 3). The soil order basically describe a dominant characteristic of a very large group of soils. Those orders found in Montana include:

1) Alfisols: Soils with relatively high base saturation, surface horizons which are low in organic matter or relatively shallow ochric or umbric and have silicate clay accumulation in sub-surface horizons. These are generally productive soils. Plant available water is present for more than half the year.

2) Aridisols: Soils which are dry throughout most of the year. Generally these soils have undergone significant development but are limited by

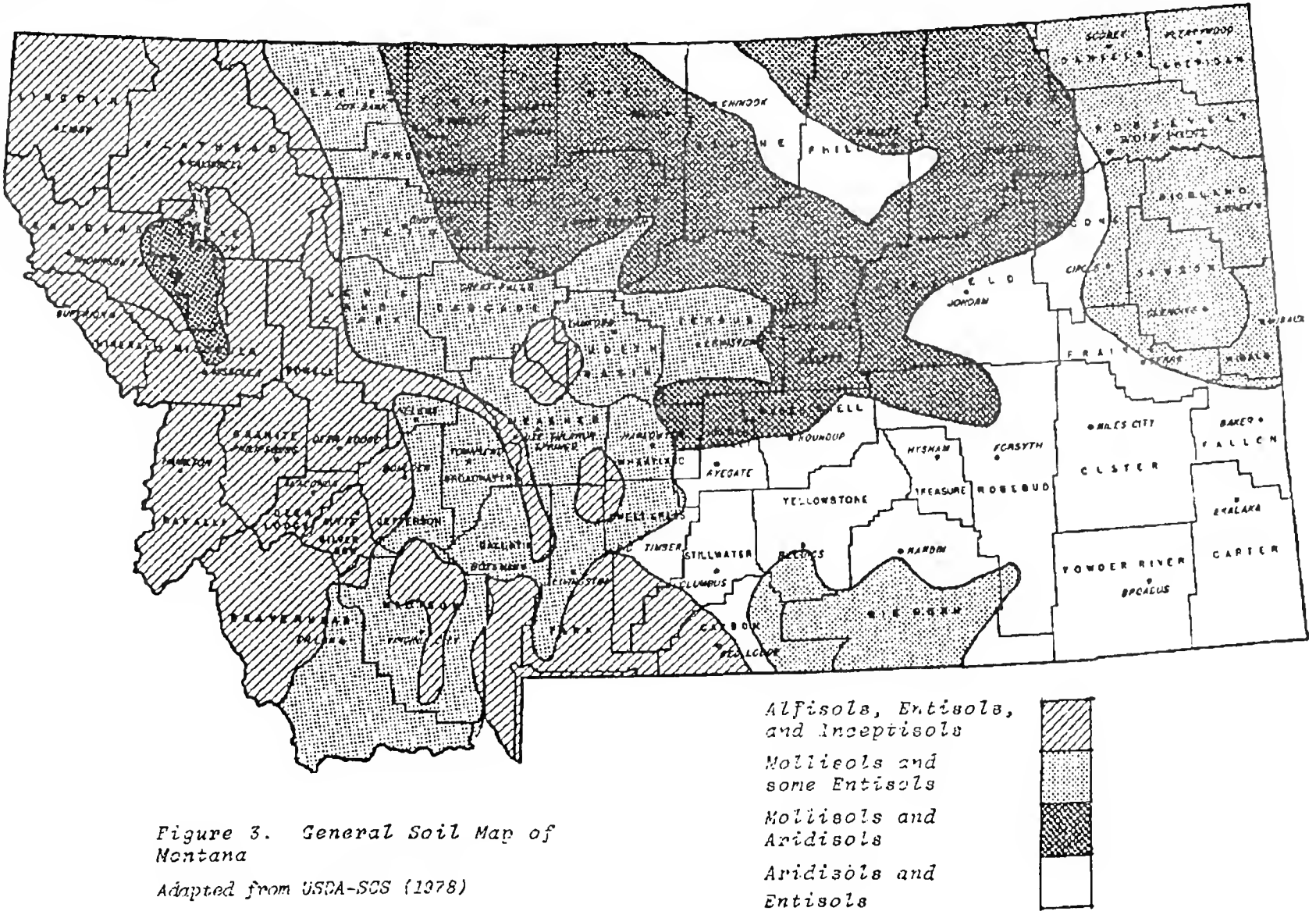

Figure 3. General Soil Map of Montana

Adapted from USDA-SCS (1978)

their dry climate and lack available water for mesophytic plants over extended periods of time.

3) Entisols: Soils which have undergone little development due to the absence of any major set of soil forming factors. Surface horizons are not significantly darkened by humus, generally infertile, lack water holding capacity and thus support limited vegetation.

4) Inceptisols: Soils which have one or more pedogenic horizons but have limited development and lack accumulation of silicate clay, iron oxides, or aluminum oxides. May be relatively fertile but are limited by a plant growth inhibiting factor and generally have rock at shallow depths. Must have plant available water for more than half the year.

5) Mollisols: Soils characterized by a dark brown or black surface horizon which is rich in organic matter and greater than 10 inches thick. These soils generally form under grasses in climates with a pronounced seasonal water deficit. They are highly fertile soils.

Any management decisions or serious consideration of soil type should be based on a detailed soil map and an actual characterization of the soil in question. The soil map given in this document serves only for general reference.

Vegetation

The state grasshopper emergency program was designated strictly for the control of grasshoppers on cropland. However, this EIS must also consider non-ccropland, because effective control of grasshoppers requires consideration of neighboring lands which are not under cultivation.

As stated earlier cropland vegetation consists primarily of wheat, barley, and hay. Native rangelands in the geographic areas affected by the emergency program consist primarily of mid-grass prairie species. These grasses may be found in headlands, pasture lands, Conservation Reserve Program (CRP) land, preserve lands, and other non-cultivated lands. Waterways and uplands are often populated by coniferous or deciduous trees. Examples of dominant vegetation found in areas likely to be treated for grasshoppers include; western wheatgrass, crested wheatgrass, blue grama, needle-and-thread, bluebunch wheatgrass, Idaho fescue, big sagebrush, silver sagebrush, ponderosa pine, and plains cottonwood.

Terrestrial Wildlife

A myriad of animal life thrives in crop and rangelandregions of Montana. Amphibian life includes toads, frogs, and salamanders. Reptilian life includes snakes, turtles, and lizards. Mammalian life includes small burrowing mammals such as shrews, pocket gophers, ground squirrels, prairie dogs, marmots, mice and others. Larger mammals include the badger, skunk, muskrat, porcupine, coyote, red fox, raccoon, river otter, mountain lion, bobcat, elk, mule deer, white-tail deer, antelope, and black bear. Arboreal mammals include bats and squirrels (Thompson 1982).

More than 200 species of wild birds populate the crop-land regions of Montana. Upland game birds include sharptail grouse, ruffed grouse, sage grouse, ring-necked pheasant, gray partridge, and wild turkey. Waterfowl of Montana include geese, a number of species of ducks, and swans. Other birds found in wetland habitats include herons, cranes, loons, killdeer, gulls, and the pelican. Predatory birds include hawks, eagles, falcons, and owls. A host of smaller birds inhabit Montana including doves, swallows, king fisher, flicker, flycatchers, horned lark, bluebirds, wrens, jays, magpie, sparrows, blackbirds, meadowlark, and grosbeaks to name a few (Skaar 1985).

Many beneficial and non-pest insects occupy the cropproducing areas of Montana. Though all insects are important members of the ecosystem many actually increase crop productivity by reducing numbers of insects destructive to crops and by acting as pollinators. Examples include field crickets, tachnid flies, hover flies, honey bees, bumblebees, leaf cutting bees, butterflies (painted lady, viceroy, silver & blue), wasps, and ladybugs. Common spiders include goldenrod, common grass spider, orb weaver, and the metaphid jumping spider.

According to the U.S. Fish and Wildlife Service (FWS)there are five endangered species of wildlife in Montana; the whooping crane, black-footed ferret, gray wolf, American bald eagle, and the peregrine falcon. Three federally threatened species in Montana are the piping plover, the least tern, and the grizzly bear. Those species most likely to be affected by the grasshopper emergency program include the peregrine falcon, piping plover, bald eagle, whooping crane, and the black-footed ferret, which may already be extinct in the state of Montana (Flath 1984).

Water Resources and Aquatic Life

The availability as well as quality of Montana's waterresources vary both temporally and geographically. Mountain lakes and streams are probably some of the purest in the nation; however, some water quality problems do exist in Montana some of which are mentioned in individual regions. Figure 5 is a generalized map of the major surface water features of Montana.

Water features of Montana range from small glacial lakes, rushing streams, and deep reservoirs in the mountainous regions to large winding streams and rivers in wide flood plains, small ephemeral tributaries, large and small reservoirs, prairie potholes, and some natural lakes in the intermountain piedmont and prairie regions. Groundwater and surface water serve as irrigation and domestic drinking water in both areas. Waterways of both areas are also a major source of energy with 22 large scale hydroelectric power plants located in Montana (Figure 4) (DNRC 1976). The quality of Montana's groundwater has gone from relatively pollution free to significantly threatened in some parts of the state (DHES 1986). Groundwater is of the highest quality in the west and lowest in the east.

Surface waters of the intermontane piedmont and centraland eastern plains are home to an abundance of aquatic life. Game fish in this region are both native and introduced. Popular species include rainbow trout, brown trout, brook trout, northern pike, large mouth bass and walleye. Flathead minnow, Iowa darter, creek chub, brook stickleback, emerald shiner, paddlefish, and carp (paddlefish and carp are considered game

NSERT FIGURE 4

fish to some individuals) are some of the most common nongame fish. Other aquatic organisms include a myriad of aquatic insects, crayfish, plankton, snails, diatoms, algae, small invertebrates, and protozoans (Brown 1971).

Air Quality

The Clean Air Act, as amended, divides the state into 5 geographical regions termed air quality control regions (AQCR). Each AQCR has distinct meteorological patterns, topography, and industrial influences. Standards set by the act require that ambient air concentrations of 6 pollutants (particulates, sulfur dioxide, nitrogen-oxides, carbon monoxide, ozone, and lead) not exceed particular levels over periods of time (DHES

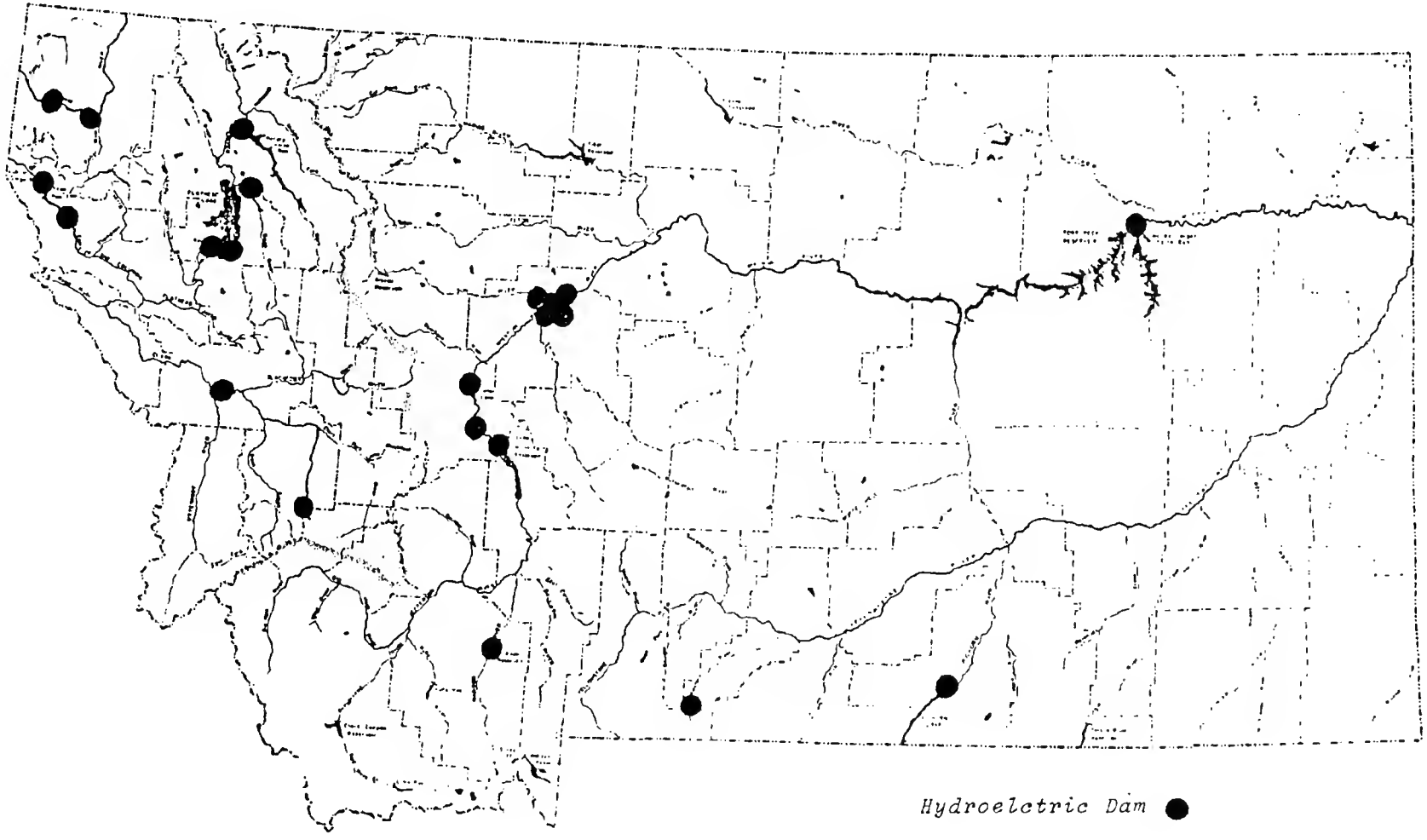

Figure 4. Major Water Features of Montana

Adapted from DNRC (1976)

1987). Low human population densities within Montana have allowed the state to maintain relatively clean air. The Montana Air Quality Bureau (DHES 1987) identified only 13 problem sites throughout Montana, 7 of which are "likely toviolate standards" and 6 of which "may violate standards". Most of these sites are in urban or industrial areas while the rest of the state is in attainment (below enforcement levels).

Human Populations

Montana is a state characterized by sparse populationspread over a great expanse of agricultural and mountainous areas. Montana's approximate 778,000 residents (1980 Census) are relatively well dispersed throughout the state (Figure 5). Headlands of mountainous regions and major waterways delineate the most densely populated areas. Only 8 urban centers in Montana have populations greater than 10,000 people.

Cultural Resources

The scenic beauty embodied by Montana's borders iscertainly one of its most valued assets. Much of the land within the Rocky Mountains is designated to national forests and national parks. Montana has 6 parcels of the national park system (including Glacier and part of Yellowstone National Parks), 15 National Forests, and over 450,000 acres in state parks. A number ofexpansive wildlife preserves are found throughout the state. Historical and archeological sites are common in Montana and are an important non-renewable resource.

Land uses other than cropland include livestock grazing, forestry, and outdoor recreation. Approximately 60% of all land area in Montana is devoted to ranchland. The quality of ranchland is dependent upon climate, slope, soil type, soil salinity, grazing history, and range management. These factors affect stability and diversity of vegetation.

Forest products account for greater than 16% of Montana's cash receipts (MDA/USDA 1987). Lumber production is primarily limited to mountainous and heavily timbered areas of Montana. Lumber production has increased from a low in 1982 of 895 million board feet to 1,662 million board feet in 1988, the highest production in Montana's history (Montana Bur. Bus. Res. 1988).

Tourism and recreation are of great social and economic value to Montana. Tourists come from all over to explore the lore of Montana.

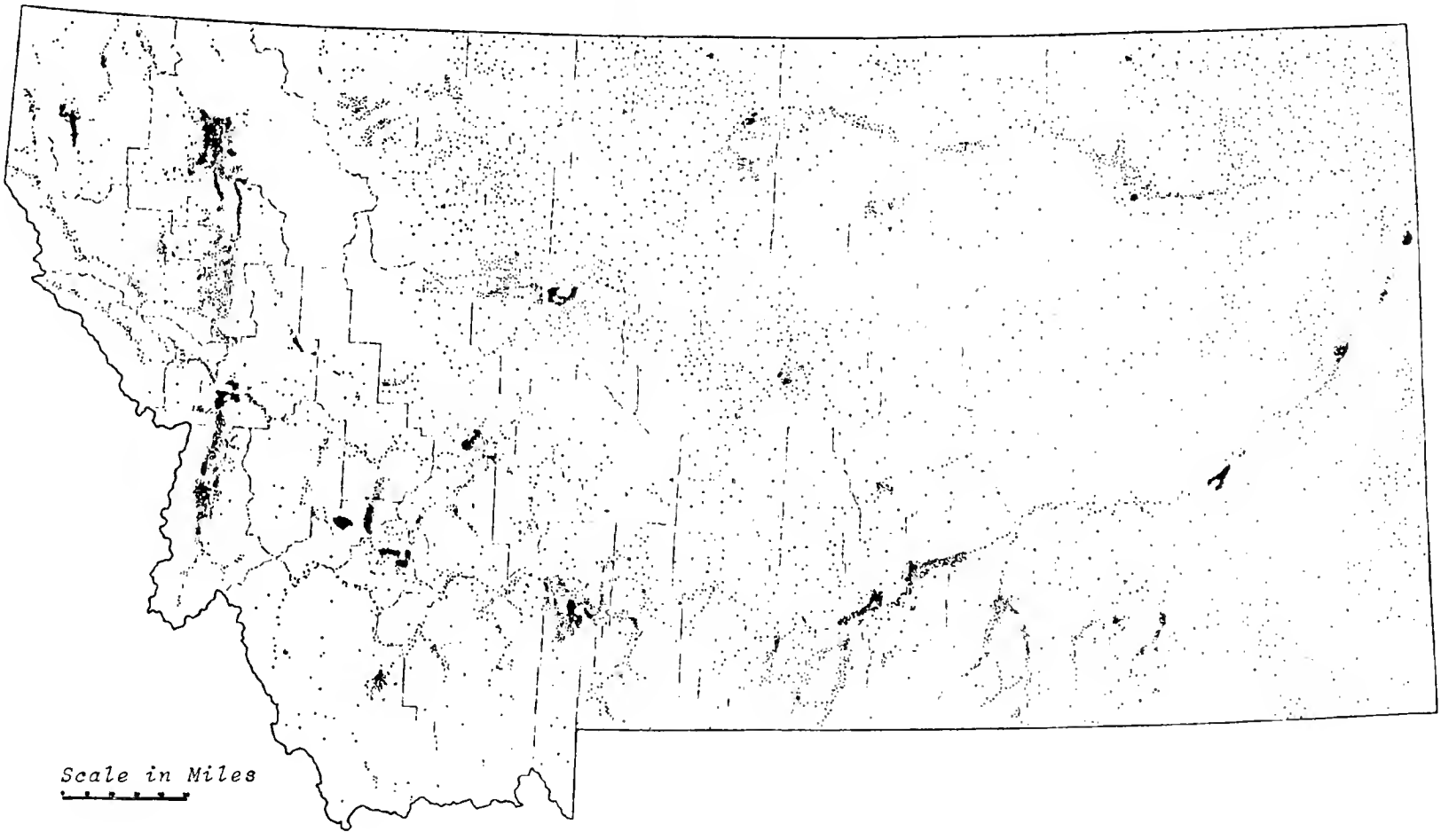

Figure 5. Population Distribution of Montana

Each dot represents 25 dispersed inhabitants

Adapted from Taylor et al. (1974)

The vast acreage of national forest and other public lands provide the public with opportunities for hiking, camping, hunting, sight seeing, skiing, bicycling, and rock climbing. Rivers, natural lakes, and reservoirs are sites for swimming, fishing, boating and other recreational activities.

Montana's mineral reserves are also an important compo-nent of the economy and character of the state. Non-precious minerals mined in Montana include metals such as lead, copper, zinc, and aluminum. Non-metals include bentonite, limestone, phosphorus, sulfur, and talc. Fossil fuels of Montana include coal, crude oil, and natural gas.

Four Environmental Regions

The following divides the state into four environmental regions based on geographic, climatic, and agricultural factors, and on the environmental regions designated by the EQC (1972). The four regions, outlined in Figure 2, are the Rocky Mountains, the Rocky Mountain forelands, the central dry plains, and the two rivers region. Grasshopper infestations in the Rocky Mountain region are primarily isolated in broad valleys.

Rocky Mountain Region

Bedrock geology of the Rocky Mountain region is primarily characterized by fine grained metamorphic rocks in the north and a combination of tertiary valley fill and intrusive igneous rocks in the south. Surface geology consists of continental glaciation in the northwest corner, piedmont and alpine glaciers within mountain ranges, glacial lakes, alluvial deposits, and eolian deposits in intermountain areas (Montagne et al. 1982).

Mountain ranges generally trend north-south or northwest-southeast and are separated by flat valley floors and foot hills. The vertical dimension determines climate, vegetation, soil, and biology in this region.

The changes in altitudinal gradients allows for further separation of this region into 6 attitudinal zones as follows:

1) Alpine tundra is the zone above timberline. Vegetation consists of alpine grasses, wild flowers, and low shrubs. The climate is too severe for tree growth and the fragile ecosystem is unsuited for excessive grazing or recreation. Soil orders of this zone are almost exclusively entisols.

2) Subalpine forest contain dense or park like stands of white bark pine, engelman spruce, and subalpine fir. Summer frosts are too common for agricultural crops.

3) Montane forest is characterized by conifers and stands of aspen. Summer frosts are not as common in this zone, thus allowing for limited agricultural activity where slopes permit. This is a zone of heavy logging. Soils may be alfisols, entisols, or mollisols, with the best soils in depositional areas.

4) Subhumid prairie parkland is less humid than upper zones and consists of prairie bunchgrass, savanna, and patches of forest. This zone is excellent for dryland farming and grazing. Eolian deposits and alluvial deposits are common, allowing for the formation of alfisols and mollisols. Aspect of slope, drainage and time since last depositional event influence soil formation.

5) Semi arid steppe zone is dry but not arid. Vegetation consists of bunchgrass and some areas of sage brush. It is a zone of irrigated farming. Soils are primarily alfisols, aridisols, and mollisols.

6) Flood plain zone has a high water table that supports stands of cottonwood, ponderosa pine, juniper, and in some cases alder and willows. This land may be cleared for agriculture which may be very productive in the fertile soils of the flood plain. Soils may be alfisols, entisols, inceptisols, or mollisols (dominated by entisols and alfisols, see Figure 3).

The northern mountains and the Beartooth and Absaroka Ranges are fairly humid and extensively glaciated. The broad valley mountains of the south tend to be dry and less glaciated.

Within this region exists a vast resource of wild game; deer, elk, pronghorn antelope, bear, beaver, and game birds. Wildlife within this region thrive in the protection of several wilderness areas, 2 primitive areas, 2 National Parks, 23 state parks, and 19 game management areas.

Water quality in this region is extremely high with the exception of localized industrial or mining regions such as those near Missoula or Butte. Groundwater quality is also excellent with the exception of a few areas. Water quality in this region is reduced by low pH, high concentrations of metals such as Zn, Cd, Pb, As, Se, and Ni, and the presence of parasitic bacteria, Giardia spp. (DHES 1986). Several streams

in this region are class I blue ribbon trout streams which harbor whitefish, rainbow, brook, brown, and cut-throat trout.

Rocky Mountain Foreland

This region includes land directly east of the Rocky Mountains and some isolated mountain ranges. Uplands and isolated mountains such as the Little Rocky Mountains, Bear Paw Mountains, Big Snowy Mountains and the Highwood Mountains are included in the region.

The land area includes mountain outliers and partially wooded hills separated by grassy plateaus, prairies, and drainages. Bedrock geology is dominated by sedimentary rocks; hard sandstones and soft red shales to the north and soft sandstone, and siltstone to the south. Surface geology includes continental glaciation, volcanic ash deposits, eolian deposits, and alluvial deposits.

Soil formation is highly dependent upon parent material. Soils forming in high gravel terraces (alluvial deposits) are generally well drained and depending on events since their deposit these areas are primarily mollisols. Deep eolian deposits are generally very fertile soils with good tilth. Some salt problems are present in soils forming in association with soft black shales. Soils of this region are predominantly mollisols and alfisols; however, entisols, aridisols, and inceptisols are also present (Figure 4).

Vegetation is highly diverse, Douglas-Fir forests occur on higher slopes of mountain outliers and isolated uplands. Blue bunch wheatgrass-fescue prairie with ponderosa pine savannas occupy the subhumid prairie parkland on lower slopes. Mixed grass steppe (Western wheatgrass, blue grama, and needle grass) dominate the semi-arid steppe of the plains, plateaus, and flood plains. Floodplain forests along major waterways are dominated by cottonwood species.

Cattle ranches are numerous along the base of the Rockies and extend into the uplands. The semi-arid steppe consists of vast acreage of dryland small grains and hay crops. Flood plains along streams and rivers allow for sizeable areas of irrigated farmland. Irrigated crops include small grains, hay, sugar beets, potatoes, and corn.

The Marias, Sun, Milk, and Teton Rivers account forgreater than 275,000 acres of irrigated farm land in the north. The Yellowstone, Clark's Fork of the Yellowstone, and Bighorn rivers provide more than 277,000 acres of irrigated land in the south. Irrigation can have a profound effect on water quality by increasing sedimentation of streams through increased soil erosion and increased salinity due to dissolution of

minerals prior to return flow of the irrigation water. Fertilizers, manure, pesticides, salinity, and sediment are the potential agricultural contaminants which account for 48% of Montana's non-point source water pollution (DHES 1986). The primary contaminant is sedimentation which has been classified as severe in this region.

Groundwater quality is highly variable throughout theregion. Fine grained aquifers in the north and south reduce groundwater quality in these regions. Water quality in the central portions of the region is moderately good.

The rocky mountain forelands are habitat to a myriad ofwild life as well as a region of relatively dense human population. Two of Montana's largest cities, Great Falls and Billings, and a large number of rural communities fall within this region. Rare, endangered, and sensitive wildlife of this area include the gray wolf, black-footed ferret, peregrine falcon, bald eagle, ferruginous hawk, burrowing owl, long-billed curlew, western bluebird, wood frog, and the pallid sturgeon (Flath 1984).

Central Dry Plains

Bedrock geology in this region is almost completely composed of cretaceous and tertiary sedimentary rock. The northern portion is primarily black shale with a zone of hard sandstone and soft shale. The southeast portion of this region is characterized by soft sandstone and siltstone. Black shales are the oldest deposits and siltstone and soft sandstone are the youngest. Surface features are greatly influenced by continental glaciation which covered the area to the north of and surrounding the Missouri River. Eolian deposits may also be found throughout this area; however, no major volcanic ash deposits have been recorded this far east.

Soils of this region are primarily aridisols and entisols(Figure 3). Soils formed in glacial till to the north are high in course fragments but are generally loam or clay loam in texture (Montagne et al. 1982). Soils south of the Musselshell River are generally aridisols formed in alluvium, residuum, colluvium, or eolian deposits. Extensive shale formations, salt laden glacial till, and prolonged, dryland fallow farming on land overlying impregnable shales has resulted in the formation of many saline seeps.

The central dry plains fall entirely within the semi-aridmixed grass steppe (Coupland 1960). Vegetation is characterized in part by blue grama, western wheatgrass, needle-and-thread grass, dryland sedge, and big sagebrush. Vegetation of salt affected soils of northwest and central

portions include salt tolerant species such as alkali sacton, greasewood, and basin wildrye.

The northwestern portion of this region is the only areaof true plains in the state. This area is frequently called the "golden triangle" for it's fertile wheat production. Agriculture accounts for 92% of the total acreage. Wildlife habitat is limited; however, 19,500 acres of game management land has been set aside.

The southeastern portion of this region is considereddesert by many. It is an area of rolling hills covered by sparse grasses, sage brush, and juniper. Primarily ranchland (10% cropland), the area is a vast resource of wildlife. Several wildlife refuges are maintained in this area including the 920,000 acre C.M. Russell National Wildlife Range which surrounds FT. Peck reservoir. Coyote, mule deer, elk, white tail deer, pronghorn antelope, upland game birds and a myriad of avian fauna inhabit this preserve. This area is also a major migration stop for waterfowl and song birds. Diverse angling is found here including trout, pike, catfish, perch, and paddlefish. Endangered, protected, rare and sensitive animals which may inhabit this region include the gray wolf (Valley County), black-footed ferret, whooping crane, mountain plover, burrowing owl, spiney softshell (turtle), and pallid sturgeon (Flath 1984).

Surface water quality is reasonably good with the exception of some prairie streams that are high in total dissolved solids. Ground water quality is poor because of high salt and total dissolved solids content. Human population densities within the region are as low as 1 person per square mile in the east.

Two Rivers

Bedrock geology of this region is almost exclusively soft sandstone, siltstone, and claystone with a few areas of soft black shale. The majority of the area is influenced by the Wisconsin period glaciers evidenced by the remains of glacial lakes Glendive and Circle. The topography consists primarily of broad rolling hills that conform to the direction of glaciers. Big sheep mountains outline the ridge which stood between the two glacial lakes.

Soil formation and vegetation are greatly influenced bythe slightly higher precipitation in this area as compared to the central plains. Soils orders are primarily mollisols and entisols (Figure 3). Mollisols are the fertile agricultural soils of this region which formed under grasslands over a long period of time. This area is quite similar to the "Sweetgrass Plains" to the west including the presence of salt affected soils and oil wells.

Greater than 90% of the land area is devoted to cultivated crops. Most cropland is in wheat or barley; however some farmers are experimenting with alternative crops such as flax and millet.

Approximately 25,000 acres of parks and wildlife refugesare maintained in this area and are home to elk, deer, bear, pronghorn antelope, fox, coyote, waterfowl, gamebirds, and song birds. This region houses a migrational stop for the endangered whooping crane. Other endangered, protected, rare, or sensitive animals found in this region include the peregrine falcon, bald eagle, piping plover, mountain plover, ferruginous hawk, pallid sturgeon, and black-footed ferret (Flath 1984).

Surface water quality is fair. Suspended solids and dissolved solids are relatively high in the major rivers. Local streams are intermittent and do not support fisheries or drinking needs. Groundwater quality is questionable because it is rather high in dissolved solids. Many residents in rural areas purify their well water to make it safe for drinking. Human population densities are approximately 3.8 people per square mile (EQC 1975).

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CHAPTER FIVE

POTENTIAL EFFECTS OF INSECTICIDE USE ON THE ENVIRONMENT

Introduction

Synthetic insecticides were the primary control method used in the emergency program. This is because synthetic insecticides are currently the most effective and reliable form of grasshopper control during a severe outbreak.

This chapter is designed to be a discussion of the potential impacts of insecticide use on the environment, but it is not a discussion of actual impacts incurred during the emergency program. This approach allows for discussion of the potential impacts of insecticide use on the environment without requiring actual data, which is not available. Few reliable studies have been performed in Montana which observe the impact of normal insecticide use on the environment and no information was gathered during the emergency program to determine environmental impacts of the actual program. Since the program was simply a cost share with producers who were using their own resources to control grasshoppers, the state had no way of determining the impacts of each individual method of grasshopper control on the environment. The information given in this chapter was derived primarily from review papers, published research, and government publications. Each insecticide discussed in this chapter was registered for grasshopper control in Montana from 1985 to 1987 (Appendix A) unless otherwise noted. Those aspects of the environment that will be discussed include;

air quality, water quality, soil organisms, terrestrial wildlife (non-target insects, birds, and mammals), human health, and cumulative effects.

Each of the compounds used during the program is categorized in Appendix E by its environmental fate, toxicity to non-target organisms, and toxicity to humans. Regardless of registration and label instructions there is much controversy over the effect of agricultural insecticides in the environment. Unfortunately, there are data gaps for chronic toxicity of the various insecticides to wildlife, humans, and domestic animals. Some of these insecticides have the potential to induce lethal or sublethal poisoning in either an acute or chronic fashion. This potential is dependent on the level or duration of exposure. This is best described by the axiom; the dose makes the poison. If the exposure is well below the determined toxicity level then it is generally accepted that the exposure victim will not be adversely affected. However, different individuals may be adversely affected at lower levels than others. The combined effect of several compounds may also increase the hazard of exposure.

The compounds used in greatest volume in the emergency program were carbofuran, parathion, and malathion. The biological agent, Nosema locustae was also registered for grasshopper control and was used during the emergency program. It will not be discussed in this section as it affects only particular species of grasshoppers and crickets. Nosema locustae does not have the potential to contaminate water, air, soil, or non-target organisms under conditions of labeled use.

Insecticides, by design, attack physiological processes of insects many of which have similar or identical counterparts in other animals. Thus, insecticides are poisonous to a wide range of non-target animals including; insects, mammals, birds, and aquatic organisms. Based on toxicity and likelihood of contact, non-target insects have the greatest probability of being killed by insecticides. It has been suggested that often very little of applied insecticides ever reach the target pest (Pimentel and Levitan 1986). This indicates that much of the applied insecticide will contact the air, soil, water, crop, and non-target organisms. Many products are meant to contact plant foliage prior to, or in addition to, affecting the insect on contact. However, the blanket application of insecticide sprays may well expose many organisms living in, or in close vicinity to, treated agricultural fields.

Once insecticides reach plant foliage, soil, or water they begin to break down. Breakdown may be mediated by microorganisms or may be an abiotic process. The breakdown products, or metabolites, may be non-toxic or may be even more toxic than the parent compound. Duration of breakdown is frequently described as the half life of the compound which is the length of time required to reduce the product to

1/2 it's original concentration. This value may be given for foliage, soil, air, or water but is dependent upon several environmental conditions. For example, a product may have a half life of 2 days in surface waters but in groundwater similar breakdown may take months or even years.

A common debate which is raised over pesticide labeling is the toxicity of inert ingredients. Many feel that this is a subject which has been ignored by the EPA. An inert ingredient is defined as a substance which is intentionally added, but by itself, is not pesticidally active. Materials such as solvents, wetting agents, emulsifiers, carriers, and fillers may fit this definition. All acceptable inert ingredients are registered with the EPA (CFR 40-180.1001) and examples include peanut shells, polyethylene glycol, montmorillinitic clay, and methylisobutyl ketone. The EPA did not initially require data on the toxicology of inert ingredients outside of the oral LD50; however, as of 1987, the EPA has categorized inert ingredients according to toxicity and will require data and labeling in the future for all inert ingredients which demonstrate toxic effects. The EPA will also require data on all inert ingredients which are similar in chemical structure to chemicals with demonstrated toxic properties. The EPA has divided the approximate 1,200 registered inert ingredients into 4 categories of increasing toxicological concern. About 50 products were identified to be of toxicological concern (list 1) and 60 of potential toxicological concern (list 2) (52 FR 77). Examples of compounds on list 1 include; pentachlorophenol and chloroform and examples on list 2 include; xylene and chloroethane. Many inert ingredients are toxic to a wide range of organisms, but the level of exposure determines the potential hazard. The EPA currently grants tolerance exceptions for inert ingredients only when the chemical appears to involve no hazard to public health when it is present in or on all raw agricultural commodities for which the product is labeled (CFR 180-1001). All new inert ingredients (as well as those on list 1) that are in products in the data call-in process are required to be accompanied with toxicity data.

Air Quality

Pesticide spraying may affect air quality in several ways. Depending on the method of application and droplet size produced, the air borne particles may reduce air quality. Air quality may be reduced at the location of insecticide application, by drift of applied insecticide, or by volatilization.

Aerially applied pesticides are the most likely to affect air quality as they are most subject to drift. Even in very slight winds drift (or off-target application) from aerial application may occur due to pattern inconsistencies from prop blast and wing tip vortices. Under extreme conditions aerial applied pesticides have been reported to travel as far as 64Km (39mi) (Moore and Looper 1980). In general, smaller droplets and higher nozzle pressure will increase the potential for drift. Aerial applications also use up to 30% more pesticide than ground spraying (primarily due to drift) thus requiring larger total amounts of pesticides be applied to each field (Bull 1982).

Ground spraying of pesticides usually results in less drift and reduces the likelihood that spray particles will become air borne for extended periods of time. Maybank et al. (1978) determined that depending on nozzle and wind speed, ground spraying develops off target drift of the pesticide from 1 to 8% as compared to 25 to 35% for aircraft spraying. However, ground spraying is more hazardous to the individual applicator. Insecticides which are air borne present a health hazard to humans from inhalation or dermal contact. This may result in acute or chronic poisoning which are further discussed in the human health section. Proper application of insecticides greatly reduces the potential impact on air quality.

Volatilization of pesticides is a second off target movement of pesticides. The amount and rate of pesticide volatilization is dependent on the vapor pressure of the compound, temperature, soil type, soil management, and application method (Pimentel and Levitan 1986). Pesticide vapor can be extremely toxic to living organisms; however, it frequently disperses to harmless concentrations in a short period of time. Harris and Lichtenstein (1961) found that 50% of house flies exposed to air space 0.6 - 1.2 cm above soil treated with phorate (Rampart 10G and Thimet 20G) were killed. Flies held in air space 3.1 - 3.8 cm above the same soil had a mortality rate of only 8 - 11%. A final impact on air quality is insecticide adsorption to dust and soil particles which then become air borne. Though this type of air contamination is not well documented, air borne soil particles may travel hundreds of miles (Troeh et al. 1984). However, the short half life of most compounds registered for grasshopper control greatly reduces the likelihood of this type of air contamination.

Water Quality

The quality of Montana's water resources may be affected by insecticide contamination. Insecticide contamination of surface water and groundwater may affect wildlife and human health. Pesticides may enter open water via drift, run off, or percolation. Water quality may be affected by a point source or non-point source of contaminant. Point source contamination is in reference to a localized source of contaminant such as a spill, leaky storage facility, or an improperly managed mixing/loading facility. Accidental spills or mishandling of the insecticides has the greatest potential to contaminate water. Pesticide drift may also allow insecticides to directly enter the hydrologic cycle. It is a direct label violation to apply insecticides directly to open water. The following describes the likelihood of pesticides entering open water and groundwater and its ultimate impact on the environment.

Depending on crop canopy density, a large percentage of applied insecticide may reach the soil. Beasly (1983) reported that 65% of a high volume spray applied to blueberries to control mites passed through the canopy and contacted the soil. The portion which has stuck to the plant canopy may eventually be washed to the soil by untimely rain or irrigation water. Most all land treated under the grasshopper emergency program was not irrigated. Precipitation is the primary vehicle by which pesticides might contaminate streams via runoff or groundwater by percolation.

If an organophosphate insecticide reaches a stream it is most likely to come from surface runoff. Insecticides will reach open water via leaching and return flow through groundwater only if the insecticide is relatively persistent. Organophosphate compounds generally have a rapid decomposition rate and will probably breakdown or dissipate prior to entering open waters via ground water. However, several insecticides registered for grasshopper control have a half life in water of greater than 2 weeks; diazinon, disulfoton, phorate, fenvalerate (a pyrethroid), and carbofuran (a carbamate). The low concentrations of insecticides applied to foliage for grasshopper control also reduces the likelihood of ground or surface water contamination. Systemic soil applied insecticides, spills, filling or rinsing of spray equipment near streams or shallow wells, and misuse of insecticides are the greatest cause of surface water contamination.

Insecticide solubility and capacity for soil adsorption determines the rate at which the insecticides migrate through the soil. Adsorption is determined by the insecticide characteristics and soil composition. Soils high in organic matter and clay will adsorb insecticides most readily. Organic matter has a greater effect on adsorption of insecticides in soils

than any other soil property (Weed and Webber 1974). Table 4 gives soil adsorption coefficients of selected insecticides. Soils with high adsorptive properties also generally exhibit slow water movement, which also slows movement of insecticides. The longer an insecticide is held within a soil profile the more likely that it will break down prior to deep percolation.

A sandy soil low in organic matter may allow for rapid percolation of an insecticide into the groundwater. Once an insecticide reaches an aquifer its lateral movement is dependent on the type of material of which the aquifer is composed. The course sandstone aquifer which underlies the sandy soils of central Wisconsin allows for lateral movement of up to 2 feet per day (Jackson and Webendorf 1983) thus allowing for rapid movement of contaminants from their initial site of leaching. These particular aquifers allow for an exceptionally high rate of movement while most groundwater movement is only several feet per year. For this reason, wells located nearest to the pesticide source have the highest potential for contamination.

All chemicals registered for grasshopper control are in the organophosphate, pyrethroid, or carbamate chemical families. These compounds degrade relatively rapidly in the soil (Appendix D). Organochlorines, for which registrations have been cancelled, break down relatively slowly. Rapid breakdown of insecticides is

Table 4. Measured values of soil adsorptive coefficients (Koc) for selected insecticides.

Insecticide	Koc[1]	Relative Adsorptivity
Carbaryl	230	low
Carbofuran	29	very low
DDT (NR)[2]	243,000	high
Lindane (NR)	1,080	moderate
Malathion	1,800	moderate
Methoxychlor (NR)	80,000	high
Mirex (NR)	24,000,000	very high
Parathion	10,000	moderate

1 Koc = (mg adsb pesticide/g organic carbon)/(ug/ml solution).
2 NR = Not Registered for control of grasshoppers.
Source: Curley et al. 1984

desirable to avoid persistence in the environment; however, many organophosphates and carbamates which are less persistent are more water soluble and less strongly adsorbed by soil than organochlorines (Table 4). This allows more rapid movement of insecticides through soil and into groundwater (Jackson and Webendorf 1983). The leaching potential of an insecticide (Table 5) is a good indicator of it's potential to contaminate groundwater. It should be noted that all insecticides registered for grasshopper control are relatively immobile compared other pesticides such as phenoxy herbicides.

Once an insecticide reaches the groundwater it will continue to degrade; however, lack of light and heat in these water saturated layers limit both microbial and chemical breakdown. Little or no breakdown may occur in very deep aquifers. The EPA suggests that most pesticide residues in groundwater are due to non-point source contamination.

If insecticides enter surface waters they rarely remain in solution,

Table 5. Computed leaching potentials of selected insecticides, higher numeric values are compounds less likely to leach.

Chemical	Value of Leaching Potential (computed)*
Carbofuran	2.1 x 106
Malathion	4,000
Methyl Parathion	580
Diazinon	490
Parathion	130
Carbaryl	87
Phorate	26
Chlorpyrifos	2.6

* Leaching Potential = S/P * Koc, where S = solubility (ppm), P = vapor pressure (mm Hg), and Koc = adsorption coefficient (mg/g)/(ug/ml).

Adapted from Curley et al. 1984.

but rather adsorb to particles of suspended silt, adsorb to organic matter in bottom mud, persist in surface films, or become concentrated within living organisms (Pimentel and Levitan 1986). Insecticides frequently maintain their toxicity in these forms; however, the persistence of organophosphates in water is generally fairly short (Table 6).Runoff events occur when precipitation rates exceed a soil's capacity for water infiltration. Runoff losses of insecticides from fields are a complex function of rainfall timing, hydrologic and soil characteristics, and insecticide chemistry, formulation, and persistence. Most severe grasshopper outbreaks occur during hot dry years which reduces the likelihood of heavy precipitation events which may cause insecticide runoff. However, the potential for groundwater and surface water

Table 6. Relative persistence of selected pesticides in some natural waters.

Non Persistent[a]	Slightly Persistent[b]	Moderately Persistent[c]	Highly Persistent[d]
Azinophos-methyl	Aldrin(NR) [e]	Carbofuran	Dieldrin (NR)
Carbaryl	Diazinon	Lindane (NR)	Endrin (NR)
Chlorpyrifos	Disulfoton	Toxaphene (NR)	
Malathion	Phorate		
Mevinphos			
Naled			
Parathion			

a. Half life of compound less than 2 weeks.
b. Half life of compound 2 - 6 weeks.
c. Half life of compound 6 weeks - 6 months.
d. Half life of compound greater than 6 months.
e. NR = not registered for the control of grasshoppers.
Adapted from McEwen and Stephenson 1979.

contamination by insecticide control of grasshoppers in Montana does exist. Insecticide concentrations in drinking water required to affect human health are given in Appendix D. Under dryland small grain production in Montana, it is unlikely that such levels will be reached, but low level concentrations of insecticides may lead to long term chronic health problems.

Fish are highly susceptible to insecticide poisoning and may come into contact with insecticides via runoff, drift, spills, and soil erosion. Toxicity of insecticides registered for grasshopper control to fish and aquatic organisms are given in Table 7, Table 8, and Appendix D. Poisoning of insects, aquatic organisms and small fry indirectly reduce populations of larger fish by direct contact and by bioaccumulation within the food chain (McEwen and Stephenson 1979). Application of insecticides to target fields would rarely introduce concentrations in lakes and streams great enough to poison fish. However, improper or careless application, spills, or improper cleaning of equipment may lead to lethal concentrations of insecticides in open waters. Individual fish kills were reported to the MDA in 1986 and 1987 (MDA Case # 001-86(2) and 001-87(24)). Though both were originally reported as being due to organophosphates, no dead fish were found at one site and no detectable contamination was found in either fish or water at both sites. Neither case was related to the grasshopper emergency program. The short half life of organophosphates and the rapid dilution factor in active streams reduces the likelihood of detecting these compounds in fish or water. Pyrethroids such as fenvalerate are extremely toxic to fish; however, under natural conditions fenvalerate is adsorbed to suspended solids which should reduce its potential toxicity.

Sublethal concentrations of these insecticides may reduce fish populations in the long run by reducing their ability to compete and reproduce (McEwen and Stephenson 1979). Organophosphate insecticides may lead to disruption of carbon metabolism which leads to depletion of liver glycogen and damage to the nervous system without actually killing the fish (Pant and Singh 1983). Sublethal concentrations of organophosphate and carbamate insecticides also inhibit brain cholinesterase activity, reduce brain RNAlevels, impair liver and brain functions (Ram and Sathyaneson 1985), and reduce intestinal absorption of nutrients (Sastry and Siddiqui 1985). Less desirable non-game fish, such as carp, appear to be fairly resistant to many insecticides. This may ultimately increase thecompetitiveness of carp over desirable game species, such as rainbow trout.

Table 7. Acute toxicity of selected insecticides (ppb) to 5 species of fresh water fish.
Many aquatic organisms are extremely sensitive to insecticides.

Insecticide	Rainbow Trout	Brook Trout	Large Mouth Bass	Carp	Relative Toxicity
Azinophos-Methyl	14	4	5	695	High
Carbaryl	4340	1950	6400	5280	Low
Diazinon	380	--*	--	--	Moder.
Dimethoate	19000	--	--	40000	V.Low
Fenvalerate	6	--	--	--	High
Malathion	170	200	285	6590	Mod-low
Methyl Parathion	2750	4740	5220	7130	Low

* Not Available
Adapted from McEwen and Stephenson 1979.

Daphnia (a water flea) is particularly sensitive to all of the compounds presented in Table 8.

Determining the likelihood of water contamination under this program would require an exhaustive study of each compound registered for grasshopper control. The short half life of most of these compounds in water greatly reduces the likelihood of chronic poisoning of humans, wildlife, and aquatic organisms.

Soil Organisms

The effect of pesticides on soil organisms such as insects, protozoans, arthropods, fungi, and bacteria is frequently questioned. These organisms are extremely important in the breakdown of organic matter and general conditioning of the soil. This is basically the same process that keeps humans from swimming in their own waste. This process is also part of the dynamic cycle which breaks down organic and inorganic complexes

Table 8. Acute toxicity of select pesticides (ppb) to aquatic organisms.

Insecticide	Red Crayfish LC50	Daphnia EC50	Stone Fly LC50	Fowlers toad Tadpoles LC50
Azinophos-Methyl	--*	3.2	8	680
Carbaryl	3000	6.4	30	7600
Diazinon	--	0.9	60	--
Malathion	170	1.8	35	--
Naled	4000	0.4	27	2200
Parathion	400	0.6	8	1600

* Not Available
Adapted from McEwen and Stephenson 1979.

into elements and compounds available for plant growth. Bacteria and fungi are the driving force behind nutrient cycling; freeing phosphorus, nitrogen, and sulfur from plant residues returning them for plant use the following year. Both leguminous and free living bacteria may also convert atmospheric nitrogen into plant available nitrogen.

The loss of large quantities of soil organisms may result in reduced soil productivity. The effect of insecticides on soil microorganisms has been studied in some detail; however, results have been somewhat inconclusive. The following will discuss the effect of insecticides on soil microorganisms followed by larger soil organisms.

The majority of the work suggests that insecticides have little long term effect on populations of soil microorganisms (McEwen and Stephenson 1979). However, the combined use of inorganic fertilizers and synthetic insecticides over an extended period of time may favor the development of microorganisms that are incapable of breaking down plant residues. Populations of soil microorganism fluctuate greatly with the presence of different residues in the soil. Bacteria and fungi are extremely important in the breakdown of insecticides in soil. Many of these organisms actually use these compounds as a source of energy. Organophosphate degrading organisms include bacteria such as Pseudomonas spp., a Thiobacillus sp., and a Bacillus sp., and a Trichoderma sp. fungus. Methyl carbamate

degrading organisms include a Pseudomonas sp. bacteria, and an Aspergillus sp. and a Rhizopus sp. fungus (Kaufman 1974).

Microbial degradation of an insecticide may indeed result in its detoxification; however, soil factors, climate, and agricultural practices may disrupt this process. Whether extended use of insecticides permanently effects populations of soil microorganisms is unknown. Assuming that microbial breakdown of insecticides occurs rapidly and at a fixed rate may result in incorrect management decisions that endanger other organisms.

Soil invertebrates; earthworms, spiders, mites, slugs, protozoans, and insects are more adversely affected by insecticides than microorganisms. These invertebrates are far more closely related to the target insects than microorganisms and are thus more susceptible to insecticides. Generally, populations of surface dwelling organisms are more readily affected by insecticides than sub-surface organism (McEwen and Stephenson 1979). Turf managers at golf courses often try to eliminate earthworms to avoid the formation of surface castings which may disrupt the roll of golf balls. Applications of 20 lb/a of carbaryl have been recommended to achieve sufficient control of earthworms (McEwen and Stephenson 1979). This is 13 to 40 times greater than the 0.5 to 1.5 lb/a recommended for control of grasshoppers on small grains (Capizzi et al. 1988). Edwards and Thompson (1973) compiled evidence which showed that though most organophosphate insecticides will not kill earthworms; phorate, carbaryl and carbofuran are highly toxic to earthworms and parathion and disulfoton are slightly toxic to earthworms. They also stated that most insecticides are not toxic to earthworms at the doses normally applied. Organophosphates were shown to significantly reduce soil populations of predatory mites (Thompson 1973).

Levels of insecticides used in one grasshopper control treatment should only temporarily suppress populations of earthworms, but may have more of a lasting effect on other soil invertebrates. The cumulative effects of insecticide treatments along with herbicide and fungicide treatments may have a more significant effect on soil invertebrates including earthworms. A review article that addresses this topic in more depth is written by Sanborn et al. (1977).

Terrestrial Wildlife

For the purpose of this discussion, wildlife will include non-domestic birds, mammals, and nontarget insects. Domestic bees will also be discussed in this section as they are the most commonly studied nontarget

insect. Insecticide control of grasshoppers has the potential to affect wildlife both directly and indirectly.

Nontarget Insects

Targeting one adverse pest may result in the loss of beneficial and economically important insects. Pollinating insects will generally be found in great numbers whenever particular crops approach bloom. Spraying of insecticides at bloom will most likely result in poisoning of nontarget insects. Most insecticides are nonselective and thus are extremely toxic to most insects. Because of their economic importance honey bees and leaf cutting bees are the most commonly studied non-target insect (Wilson et al. 1988, Moffet et al. 1986, Stoner et al. 1982, Caron 1979).

Honey bee kills due to insecticides during the 1960's led to the legislation of the Bee Indemnity Act of 1972 (PL 91-524) to compensate apiculturalists for their losses. Between 1972 and 1976 the Agricultural Stabilization and Conservation Service (ASCS) paid over $21 million in indemnities (Pimentel et al. 1980). Large block spraying has the greatest potential for bee kills because of the high levels of drift. Large block spraying of grasshoppers with ULV carbaryl (Sevin 4-oil) by USDA-APHIS in Rosebud County in 1987 resulted in bee kills in a non-target field (MDA Case # 87-032). Even with small acreage treatments bee losses occurred in Montana (MDA Case # 86-013, 86-018, 87-024, 87-036, 87-021 and 87-033). Two cases involving losses at five apiaries due to insecticide drift are currently being investigated. One case involving alleged bee losses at four apiaries was due to a block a grasshopper control program. Losses were a result of not moving bee hives, returning them to the treated area too rapidly, drift of insecticides, and bees visiting target fields. The MDA EMD has made available a set of guidelines for apiculturalists and insecticide applicators, which gives information that should help both parties avoid bee kills.

Losses due to total bee kills, partial bee kills, moving apiaries and reduced pollination have a serious impact on honey production and crop productivity. Martin (1978) estimates that approximately 20% of all honey bee colonies are affected by pesticides, 5% of which are total bee kills. Martin also suggests the cost of partial bee kills in the US is $21 million annually.

Annual agricultural losses due to poor pollination from insecticide damage is estimated between $80 to $400 million (Pimentel et al. 1980). Wilson et al. (1988) demonstrated that aerial applications of ethyl-parathion to blooming sunflower caused great losses of adult honey

bees in colonies adjacent to the sprayed field. The first and second sprays caused a 99% and a 94% reduction in collection of sunflower pollen and a 73% and 96% reduction in collection of other pollens. Two days after spraying, pollen collection began to increase slowly but remained significantly less than pollen collection from the control (untreated) field. This may also have an adverse affect on non-crop vegetation which requires cross pollination to maintain genetic diversity and survive as a species.

Beneficial insects lost during pest control have been infrequently studied. Examples of beneficial insects include; the caterpillar of the painted lady butterfly (eats thistles), tachnid fly (aphid parasite), lady beetle (consumes aphids), scelionid wasps (grasshopper egg parasite), and pollinating insects such as butterflies, bees, wasps, flies, and moths. Insects also provide a significant food source for other animals and are important in decomposition of plant and animal materials.

Miller and Kevan (1979) reported significant declines in populations of 11 genera of arthropods in fields treated with disulfoton or carbaryl. They also mention that these organisms may not have genetic plasticity, like most insect pests, to develop resistance to insecticides. A study of butterfly populations in cereal fields treated with pesticides resulted in a significant decline in all butterfly populations, compared to fields receiving no treatments (Rands and Sotherton 1986). Insecticide control of insects may leave the agricultural ecosystem open to continued infestations by destructive insects, because many natural predators are destroyed in the process.

Birds

Larger organisms are also affected directly and indirectly by insecticides. Birds may be directly affected by contact with insecticides and indirectly by reduction or contamination of food sources. Most insecticides registered for grasshopper control have a short half life in the environment, thus most poisonings are probably due to acute exposure to pesticides. Perhaps more common than lethal effects of pesticides on birds and mammals are sublethal exposure which may increase the organism's susceptibility to disease, of starvation, disorientation, predation, and reduced reproductive success (Pimentel and Levitan 1986). Putting an economic value on wildlife is difficult, especially when losses haven't been recorded; however, the U.S. Fish and Wildlife Service underwrites $10 million annually to monitor the impact of environmental contaminants (60 - 70% of which is agricultural) on wildlife.

Lethal concentrations of some registered grasshopper control compounds are given in Table 9 for mallard duck and pheasant.

Game bird hunting is a prized sport in Montana. No game bird kills in 1985 - 1987, due to compounds registered for grasshopper control, were reported by the Montana Department of Fish Wildlife and Parks or the MDA. However, a producer and local ditch rider in Roosevelt county claimed that game bird populations declined rapidly during a grasshopper outbreak in 1986 when most of his neighbors were spraying insecticides to control grasshop) Whether or not such cases were common or were directly correlated with insecticide use was not determined. There is a high potential for exposure of birds to insecticides as many game birds populate rangeland, cropland, and field margins; however, the probability of lethal or sub-lethal poisoning is unknown. Game bird surveys by the Montana FWP showed no fluctuations in populations that correlate with the grasshopper emergency program.

Table 9. Acute oral and dermal toxicity of selected pesticides to pheasant and mallard duck.

	Oral LD50 mg/kg		Dermal LC50 ppm		
Pesticide	Mallard	Pheasant	Mallard	Pheasant	Relative Toxicity
Acephate	186.0	--*	--	--	Mod.
Azinophos-methyl	136.0	75.0	1950	1900	Mod.
Carbaryl	2179.0	2000.0	5000	5000	Low
Carbofuran	0.4	4.2	--	--	High
Diazinon	3.5	4.3	--	--	High
Dimethoate	41.0	20.0	--	--	Mod.
Disulfoton	6.5	11.9	500	650	High
Malathion	1485.0	--	--	--	Low
Methyl-Parathion	6.6	8.2	53	--	High
Mevinphos	4.6	1.4	--	--	High
Parathion	2.0	4.2	--	--	High
Phorate	0.6	7.2	250	480	High

* Not Available

Adapted from McEwen and Stephenson (1979) with additions from Pimentel (1971).

Bird poisoning may be a result of direct contact with insecticides or from ingestion of contaminated insects or vegetative matter. A pheasant consumes approximately 6 grasshoppers per day during the summer months (Hiatt 1947) and sage grouse diet contains approximately 15% grasshopper during July and August (Wallestad 1975). These numbers would almost certainly be higher in the presence of grasshopper outbreaks.

Mallard ducks and pheasant are extremely sensitive to parathion, methyl-parathion, carbofuran, Mevinphos, and phorate (Table 9). The toxicity of acephate to mallards is relatively low (LD50 236 mg/kg); however, Bull (1979) reported that acephate may degrade rapidly to methamidaphos; a registered acaricide which has an LD50 of 8.5 mg/kg for mallards (highly toxic). Songbirds and raptors are also susceptible to organophosphates and carbamates. Recently several bald eagle kills have been linked to carbofuran misuse in Delaware (Cress 1989).

A reported 1,400 ducks died of carbofuran poisoning in grain fields of British Columbia between the years of 1973 to 1975 (Flickenger et al. 1980). Alfalfa fields in Oklahoma treated with flowable carbofuran resulted in the death of 500 Canada geese (Flickenger et al. 1980).

Researchers have investigated the numbers of birds killed from normal (labeled) insecticide applications to cultivated fields. In a study by Flickenger et al. (1980) carbofuran granules applied to rice in Texas resulted in the death of sandpipers and red wing-blackbirds within 24 hours of treatment. A treatment of 1.12 kg carbofuran granules/ha to a 405 ha (810 a) corn field in Maryland (to control corn root worm) resulted in the death of at least 5 songbirds (Balcomb et al. 1984). Agricultural fields bordered by waterways were treated with 1.4 kg/ha of methyl-parathion and then observed for changes in duck populations and habits (Brewer et al. 1988). Brood abandonment and nesting mortality was observed on the field treated with methyl-parathion. Brood survival of ducklings was 58% for the untreated field and only 13% for the treated field.

Acute oral toxicity, repellency, and a poisoning potential index for redwing blackbirds is given in Table 10. The poisoning potential index described by Schafer et al. (1983) is based on the amount of pesticide a bird might consume following a spray event. Azinphos-methyl, carbofuran, disulfoton, methyl parathion, parathion, and phorate are insecticides registered for grasshopper control that are most likely to poison avian fauna. Sublethal effects of insecticides may result in the eventual decline in local bird populations.

Mammals

The influence of grasshopper infestations on mammals has not been studied to any great extent. Onsager (1984) suggested that the average rangeland grasshopper consumes 9, 22, and 53 mg of forage per day in the 4th instar, 5th instar, and adult stages respectively. Thus, densities of 9 adult grasshopper per square yard could consume 2.4 kg forage/ha each day (2.5 lb/a). According to these calculations grasshoppers have the potential to compete with wild and domestic mammals for forage in an outbreak year. Foraging animals such as antelope or deer probably do not benefit from grasshopper outbreaks; however, coyotes, foxes and other mammals consume large quantities of these high protein insects during summer months.

Table 10. Acute oral toxicity, repellency, and poisoning potential index for selected pesticides to redwing blackbirds.

Pesticide	LD50	R50[a]	Hazard[b] Index	Poisoning Potential
Azinphos-methyl	8.2	12.3	1.54	High
Carbaryl	56.2	16.2	0.29	Possible
Carbofuran	0.4	2.2	5.11	High
Chlorpyrifos	13.3	6.4	0.48	Possible
Diazinon	2.6	1.5	0.77	Possible
Disulfoton	3.2	7.0	2.19	High
Malathion	400.0	119.0	0.30	Possible
Methyl-Parathion	10.0	24.5	2.45	High
Parathion	2.4	10.2	4.31	High
Phorate	1.0	3.6	3.62	High

[a] R50 = Repellency index; concentration at which 50% are repelled by the compound.

[b] Hazard Index; 1.0 High possibility of poisoning, 0.25 - 1.0

Possibility of poisoning, 0.25 Low possibility of poisoning. Adapted from Schafer et al. 1983

Insecticide control of grasshoppers might relieve the food pressures imposed by grasshoppers, but they may threaten the health of mammals. Acute oral toxicities of some insecticides registered for grasshopper control are given for mule deer and rats in Table 11 and complete listings are given in Appendix E. Relating these values to the likelihood of poisoning wild mammals is not simple. Wild mammals do not "float to the top" like dead fish in a pond. Those mammals affected by insecticides may return to their den or burrow before dying or if left dead in a field are rapidly consumed by scavengers. Thus, few reports of wild mammal kills by insecticides are available. Proper handling and application of insecticides greatly reduces the possibility of contaminating wildlife.

Balcomb et al. (1984) studied cornfields treated with granular carbofuran. Within 24 hours of treatment a dead white- footed rat was found containing 15.1 mg/kg of carbofuran (LD50 for rat is 11 mg/kg). Organisms living in treated fields are in the greatest danger of contacting lethal levels of pesticides; however, drift, runoff, and biologic movement carry insecticides to neighboring lands. This is a special concern for parks and wildlife preserves bordering areas of treatment.

Table 11. Acute oral LD50's (mg/kg) of select insecticides to rat and mule deer.

Pesticide	Rat	Mule Deer	Relative Toxicity
Azinphos-methyl	18	32-64	High
Carbaryl	540	200-400	Low
Carbofuran	11	--*	High
Diazinon	185	--	Moderate
Dimethoate	185-245	200	Moderate
Disulfoton	12.5	10	High
Malathion	400-1500	--	Low
Parathion	4-30	22-44	High
Mevinphos	608	--	Low
Naled	430	200	Moderate

From Pimentel 1971.
* Not Reported

Humans and Domestic Mammals

Control of grasshoppers with insecticides may adversely affect human and domestic mammal health (Appendix E). Almost every human in the United States has had some contact with pesticides. The average American citizen in the 1970's contained an insecticide residue of 6 ppm (Pimentel et al. 1980). This value was most likely developed from populations exposed to organochlorine pesticides. Organochlorines are highly persistent and have the potential to accumulate in the fat tissue of the human body. There would be less potential for accumulation of organophosphates or carbamates in the human body. Most human exposure to pesticides comes from the food we eat; however, other sources include drinking water, skin contact, and inhalation of contaminated air (Pimentel et al. 1980). Food exposure should be well below any level harmful to the human body, whereas dermal and inhalation exposure of farm workers results in the majority of pesticide poisonings (Plimmer 1982).

The EPA publishes a list of tolerances for pesticide residues in raw agricultural commodities that are the "maximum acceptable limit" of pesticide residues in food and forage (CFR 40-180). Though these tolerances are set well below any known acute or chronic toxicity level, the values do not take into account the possible additive or synergistic effects of combinations of pesticide residues. Drinking water health advisories have been or are currently being published for every pesticide registered for use in the United States. These summarize the available information on the acute and chronic toxicities of these compounds to humans and other animals.

Appendix E gives the EPA tolerances for all compounds registered for grasshopper control on alfalfa, wheat, and sugarbeets. These are the maximum tolerated pesticide residues in food to ensure that lifetime human exposure will not result in cancer development. Tolerance limits are set in a conservative manner, generally concentrations 100 times lower than that observed as the no observable effects level (NOEL). The EPA also considers the dietary intake of sensitive sub-populations (i.e. children) when developing a lifetime tolerance limit. Tolerance limits impart a large margin of safety from any short term or long term toxicity due to pesticide residues in food.

Organophosphate insecticides have an extremely high oral and dermal toxicity to mammals (McEwen and Stephenson 1979). Most organophosphates are known to break down rapidly in the environment. However, metabolites (breakdown products) may also be toxic. For example, under hot dry conditions parathion breaks down to paraoxon

and further degradation occurs very slowly (McEwen 1977). Paraoxon may accumulate on the surface of foliage, which may then come in contact with farm workers or be consumed by domestic animals (McEwen 1977). This is primarily a problem in orchard or vegetable crops that require a great deal of hand labor, but treated forage crops are consumed by domestic animals . Copplestone (1977) suggested that 4 in every 1000 agricultural workers in California suffer acute sublethal poisoning, primarily due to organophosphate insecticides. Organophosphate insecticides are the primary cause of occupational poisoning due to insecticides (Plimmer 1982). Peoples and Knaak (1982) suggest that agricultural workers can be divided into two groups with respect to pesticide exposure; those who mix, load, and apply pesticides and those who work in the treated fields. The mixer, loader, applicator are at the highest risk of poisoning but are protected by the label specifications with respect to protective clothing and proper application (Peoples and Knaak 1982). Field workers are protected by re-entry periods, but are frequently affected by misuse of pesticides by the owner or applicator. In Montana there is very little direct worker contact with treated foliage as the majority of crop production is devoted to grains.

Fatalities due to pesticides are generally caused by accidents or improper handling of the chemicals. Pimentel et al. (1980) estimated a total of 45,000 pesticide poisonings each year, 2,500 of which are hospital admissions and 200 of which are fatal (EPA 1976). Sublethal, chronic exposure to insecticides may result from improper handling of pesticides and may result in blood dyscarasias, allergy sensitivities, neurological changes, hypertension, immune system failure, high blood cholesterol, cardiovascular disease, birth defects, and cancer (Pimentel et al. 1980, Exon et al. 1987). Sublethal, acute poisoning symptoms include vomiting, weight loss, diarrhea, hyperglycemia, anemia, headaches, disorientation, nausea, blurred vision, and nerve disorders.

Persistence of such symptoms may indicate that a person is accumulating or retaining the compound in their body. Mild cases of poisoning may occur regularly but are not reported. Agricultural producers and rural dwellers have complained of insecticide drift to their residence from aerial spraying of neighboring fields. This may result in direct contact of humans, livestock, and pets with the applied chemical, and contamination of the residents property.

Domestic animals may consume contaminated food or water or come in direct contact with a pesticide. A survey of veterinarians in South Carolina and Arkansas found that dogs and cats are the most likely domestic animals to be poisoned by agricultural pesticides. An estimated $3.1 million of livestock are lost to pesticide contamination (generally

through misuse) each year, and a total of $11.9 million of all meat and milk products are lost annually to pesticide contamination and subsequent poisoning or rejection at market (Pimentel et al. 1980).

Cumulative Effects

Insecticide use may reduce numbers of beneficial organisms that feed on grasshoppers, other insect pests, and weeds. Grasshopper populations have the potential to rebound from insecticide control much quicker than their natural predators. Reduction of beneficial organisms forces the producer to continue use of chemical control for grasshoppers as well as other insect pests. Such continued increased insecticide use also increases the likelihood that pests will develop resistance to the insecticides. This reduces the efficacy of the insecticide and requires more use for each treatment. The USDA claims that our insect pest problems have actually worsened since the onset of synthetic insecticide use.

Insecticide use may also endanger fish, and wildlife through direct contact or contamination of food or water supply. This may also hurt regional economies by reducing numbers of hunters, anglers, and sightseers that frequent the area.

Continuous exposure of man and domestic animals to insecticide vapors and sprays may result in chronic illness or accumulation in the body and resultant long term effects. Pesticide residues in domestic animals may also increase human exposure if the domestic animal is consumed. The combined or cumulative effects of several different agricultural chemicals in the human body poses a health hazard which has yet to be determined. Exposure to two or more insecticides of similar mode of action may have a synergistic adverse effect on human health. Such effects have been studied in some depth, but are not known for most combinations.

Drift is the most common form of chemical trespass which may lead to: 1) reduction of air quality, 2) decreased water quality, 3) reduction of natural enemies of pests on lands not treated with insecticides, 4) reduced pollination, 5) reduced honey production, 6) losses of desirable species from sensitive areas, 7) contamination of organic farms or private gardens, 8) reduced livestock quality, 9) livestock illness or death, and 10) public opposition to the use of any pesticides.

Pesticide runoff is another form of chemical trespass. Generally, once insecticide runoff leaves a field it becomes so dilute that it poses no immediate threat to aquatic organisms. Streams in areas of intensive

agriculture may have enough sources of insecticides present to have an aversive effect on aquatic organisms.

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CHAPTER SIX

ALTERNATIVE STRATEGIES FOR STATE ASSISTED GRASSHOPPER MANAGEMENT

Introduction

This chapter considers the alternative strategies available to the State of Montana to both assist in grasshopper management in cropland and neighboring non-cultivated land during years of severe grasshopper outbreaks and attempt to alleviate the occurrence of future severe outbreaks through programs enacted during years with mild or nonexistent outbreaks. A significant amount of research on grasshopper management has been conducted, but the approach to control has changed very little over the last 40 years. Grasshopper populations may change markedly from one year to the next. Non-destructive levels of grasshoppers may erupt into populations capable of denuding cropland within a year. For the last 80 years our response to grasshopper outbreaks has been to treat cropland with insecticides. Originally achieved by spreading arsenic baits, more recently, by spraying with synthetic chemical insecticides. At their onset, many felt that modern chemicals would rid agricultural fields of insect pests (Morrill 1983); however, it was quickly realized that these chemicals provided only temporary control. Populations of grasshoppers might return within that same season or the following season depending on environmental conditions. The USDA claims that insect pest problems have worsened since the onset of synthetic insecticides in the late 1940s.

Grasshoppers are still a major agricultural pest in Montana as evidenced by widespread infestations in Montana in 1985, 1986, and 1987.

Even during years of low or medium population levels, grasshoppers destroy approximately 21-23% of range forage annually (Onsager 1987). Yield reduction is the primary concern of producers; however, cost of insecticides and application can reduce the net return on a crop. Producers may benefit by concentrating on maximizing returns rather than yields.

The following chapter will identify alternative strategies for state assisted grasshopper control. These alternatives would ideally be safe for the environment, effectively reduce the economic impact of grasshopper infestations, and reduce the occurrence of grasshopper infestations. The alternatives presented are based on written and oral comments solicited from the public and substantiated by available documents and research reports. Public scoping sessions were held at three locations in Montana:

1. May 16, 1988, Fort Benton.
2. May 24, 1988, Plentywood.
3. May 25, 1988, Billings.

Over 300 mailings were sent to state, federal, and local government officials, public and private interest groups, and various research institutions in an attempt to solicit opinions.

Alternatives which were developed are broken down into two groups; emergency and non-emergency in an attempt to differentiate between crisis reaction and mitigating actions that the department might take. Each alternative will be tested against a set of criteria that weigh economic and environmental benefits and costs. No numeric cost benefit analysis will be performed on the alternatives because of a lack of adequate information. The following chapter will be broken down as follows:

A. Alternatives Rejected
   1. Required Certification to Qualify for State Assistance.
   2. Emergency Exemptions for Use of Cancelled or Suspended Insecticides.
   3. Use of Only Biological Control in the Emergency Program.
   4. Emergency Low or No Interest Loans.

B. Emergency Alternatives Considered
   1. No Action.
   2. Elimination of State Emergency Program.
   3. Targeting State Assistance.

C. Non-Emergency Alternatives Considered
   1. No Action.

2. IPM Development Program.
3. State Supported Research.
4. State Assisted Roadside Grasshopper Control.
5. Integrated Grasshopper Management Program.

Each of these alternatives will be described in detail with respect to its efficacy and impact on economics, social values, and the environment. The following criteria will serve as the basis on which each alternative will be judged.

Evaluation Criteria

a) Environmental Impacts;
   1) air and water quality
   2) soil and vegetation
   3) wildlife
   4) human health

b) Socioeconomic Impacts;
   1) general public
   2) users of public lands
   3) rural life

c) Economic Impacts;
   1) producers income
   2) state and county revenues
   3) short term versus long term productivity
   4) rural economics

d) Cumulative Effects

A. Alternatives Rejected

The following alternatives were considered by the MDA but rejected based on technical, practical, or legal reasons.

A1. Required Certification to Qualify for State Emergency Funds

Several of the pesticides registered for grasshopper control were restricted use products. Thus only certified commercial, government, and private applicators could purchase and use these products during the emergency program. General use products (not restricted) could be used by non-certified persons during the emergency program. It was suggested however, that any person desiring to use any registered product be specially trained in the use of the specific compound they chose.

While this idea has merit in terms of providing specific safety, environmental and other precautionary information, it is not practical from a time or manpower perspective. Since the whole program has to be accomplished within 30 days (20 day emergency proclamation plus 10 days to complete treatment) it would require at least 1 to 2 persons per county to provide the training. This is further complicated by the fact that the individual producers and the product of their choice would have to be identified. Then the training sessions would have to be developed for the individual products. Once the applicators have been trained, they would be issued a certificate to present to a pesticide dealer to allow them to purchase the chemical for which they had been certified. This whole process would require far too much time and manpower resources and give very little in return and thus the alternative was rejected.

A2. Emergency Exemption for Use of Suspended or Cancelled Insecticides

This alternative would allow for the use of insecticides not registered for grasshopper control during an emergency (widespread grasshopper infestations). This option was rejected based on legal implications alone.

One of the most frequently voiced comments at scoping sessions was some producer's desire for the return of Dieldrin. Dieldrin registrations were cancelled for use in the U.S. in 1974 following investigative findings that it is extremely persistent in the environment and presents a significant health hazard (Appendix E). The loss of this compound in 1974 was noticed in 1975 when several counties in Montana declared emergency grasshopper infestations. No provisions under FIFRA as amended allow the EPA to authorize use of suspended/cancelled products (PL-92-516). There are currently 20 insecticides registered for grasshopper control on one or more of the following; small grains, corn, alfalfa, pasture and rangeland, potatoes, sugar beets, beans, sunflower,

safflower, peas, lentils, gardens, field margins, and turf and ornamentals (Appendix A). According to PL-92-516 a pesticide emergency can only exist when there are no or insufficient pesticides registered for the control of a specific pest. Thus, no pesticide emergency exists with respect to grasshopper control on any of the major crops produced in Montana.

A3. Use of Only Biological Control in the Emergency Program

The only biological grasshopper control treatment currently available is Nosema locustae, a naturally occurring microsporidian parasite of grasshoppers and Mormon crickets (described in Chapter 2). As stated previously Nosema locustae is most effective in a preventative control approach. It loses much of its efficacy once the majority of grasshoppers have reached the third instar.

Nosema is considered to give up to 50% mortality of grasshoppers within several weeks following application and then give some limited residual control for months to years following application (Onsager 1988). Since there is no way of making accurate estimates of the occurrence of grasshopper outbreaks, the state could not give emergency assistance for preventative control of an outbreak which may or may not occur. This may be a viable alternative in the future if reliable fast acting biological controls are developed.

Naturally occurring parasites and predators of grasshoppers obviously influence grasshopper populations. The populations of parasites and predators that are reliant on grasshoppers to survive would increase with increasing populations of grasshoppers. This increase would most likely lag to some degree behind that of the grasshoppers and would have little influence on populations once they reach outbreak levels. This alternative was rejected because the biologicals currently available do not respond well in an emergency situation. Biologicals used in combination with other methods of control may well be a viable alternative.

A4. Emergency Low or No Interest Loans

A recommendation submitted during the scoping process was to make emergency loans available to producers during severe grasshopper outbreaks. The primary benefits that might be gained from this program are; less total expenditure by the state on the program and only producers in need of assistance in grasshopper control would take part in the

program as they would have to pay back the loan. However, this program is impractical from a standpoint of timing and distribution of funds.

The funding for such a program could not come from the emergency fund, but rather would have to come from a general, special fund appropriation established by the legislature, or through the Ag Finance Program. However the Ag Finance Program funds are currently being used to assist youth and low income farmers. Thus, funding from this source for an emergency program would be limited at best.

The loans would have to be distributed during the emergency situation to accomplish the goal of the program. The process of applying for, reviewing, and closing a loan through government programs is typically quite lengthy. To fit the needs of farmers during an emergency outbreak situation, the loans would almost certainly have to be submitted and reviewed prior to the declaration of an emergency. Since emergency grasshopper outbreaks are not predictable and may not occur for 5 to 10 years at a time, this is not a valid alternative.

B. Emergency Alternatives Considered

The following section describes each of the alternatives considered by the MDA with regard to assistance in grasshopper control during emergency grasshopper outbreaks. Regardless of which alternative is adopted, the state should have field scouts available to accomplish the duties outlined by the Crop Insect Detection Act (MCA 80-7-502). Following budget cuts in 1986, only the MDA entomologist has provided this service. This limits the effectiveness of the entomologist position and does not provide for sufficient manpower for insect detection.

Alternative B1: No Action

This program would simply be a continuation of the current grasshopper emergency control program which has been described in detail in Chapter 3. Thus the following section will only discuss the potential impacts of the emergency program on the economics and the environment of Montana.

The impacts that will be discussed are based on an assumption that the program resulted in an incremental increase in insecticide use over that which is normally used in the state. The applications of insecticides

had to have occurred within a 30 day period. Organophosphate, pyrethroid, and carbamate insecticides listed in Appendix C are those available for grasshopper control. The maximum additional insecticide use that could have occurred during the program can be estimated at about a maximum of a 9% increase in total insecticide use in 1985. However, recall that many producers suggested that they sprayed regardless of the program (See Chapter 3 page 53). A maximum of 721,000 acres (about 0.7% of Montana's total land area) were involved in the program in any one year for one control treatment.

Alternative B1. a) Environmental Impacts

Air and Water Quality

The incremental increase in insecticide use during the emergency program may have an adverse effect on the environment. Air quality and water quality may be influenced by the additional use of insecticides. Air quality is primarily influenced by insecticide drift from aerial application and many producers had insecticides applied by aircraft under the program. Water quality would also be affected by increased use of insecticides. The primary threat to water quality comes from accidents or mishandling of insecticides. No reports of water contamination with insecticides registered for grasshopper control were received during the emergency program. However, there is little monitoring of pesticide residues in water in Montana as stated earlier, and the half life of most of the registered insecticides in water is relatively short.

The likelihood of insecticide contamination of surface waters would increase with increased use of insecticides. This would have a direct and indirect affect on fish populations in the affected surface waters. Fish may be affected by lethal doses of insecticides, sub-lethal doses of insecticides that reduce their ability to reproduce and compete, and by reduction of sufficient or healthy food supplies. Toxicity of the registered insecticides to fish range from very low to very high (Appendix C). It should be noted that during the emergency program no fish kills were reported for compounds registered for grasshopper control.

Soil and Vegetation

The increase in insecticide use under the program should have little affect on either soil or vegetation. Any affect on nontarget vegetation would be indirect. Effects on rare or endangered plant species may be positive or negative. Additional use of insecticides may reduce damage

inflicted on such vegetation by insects or rodents. However, increased use of insecticides may also reduce pollination of plant species that require insect or bird cross pollination to survive as a species. Soil may be directly affected by the use of insecticides; however, this effect should be temporary. Insecticides may reduce the numbers of soil invertebrates that are necessary for development of good tilth in a soil. Some soil invertebrates affected by insecticide use may also be predators of insect pests.

Wildlife

Non-target insects are the organisms most likely to be exposed to insecticides. Loss of beneficial organisms with the application of insecticides may increase the need for insecticides to control all insect pests. Bee kills result in a cost to individual bee keepers as well as the state. Any increased use of insecticides near apiaries increases the likelihood of bees contacting the sprays.

Birds would be more likely to contact insecticides if use increased. No bird kill complaints associated with the current program (1985 - 1987) were reported to the MDA; however, some complaints were voiced from individual farmers with respect to the disappearance of pheasants from their land during the program. Birds may be affected both directly and indirectly by contamination of a food source or direct contact with spray drift.

Mammals also have the potential to be adversely affected by an increase in insecticide use. Though smaller mammals are the most likely to be affected, insecticide drift may contaminate larger animals as well. Wildlife may also enter fields prior to expiration of the labeled reentry interval, thus coming in direct contact with insecticides in the field. If rare or endangered species of wildlife are exposed to an increase in insecticide use, loss or reduction in their populations would be an irretrievable and irreversible commitment of a natural resource.

Human Health

If the program increased insecticide use, human health may be affected by increased exposure to insecticides. Increased aerial application of insecticides may increase direct contact of humans with spray drift. Drift may also contact private proerty near the treated area resulting in indirect contact of humans with insecticides. However, careful use of insecticides and following all label instructions greatly reduces the hazards associated with insecticide use. Accidents, spills, and

careless use of insecticides may result in human exposure to insecticides. As noted earlier, insecticide exposure may range from disorientation and headaches to death. It should be noted that no human exposure complaints were lodged with the MDA as being caused under the program.

Domestic animals may also be more likely to come in contact with insecticides. Such exposure may result in illness or death of the animal. Insecticide drift, spills and improper container disposal may result in domestic animals coming in contact with insecticides. Livestock contaminated with insecticide residues may result in indirect human exposure to insecticides.

Alternative B1. b) Socioeconomic Impacts

General Public

The general public would be indirectly affected by this program. State assistance for grasshopper control reduces those funds available for other state emergencies. Additional state tax revenues, earned from assisting producers, might account for some of the money spent by the state but these returns do not affect the set amount of money available for the Governor's emergency fund of $1,000,000. Fewer grasshoppers on agricultural lands should result in fewer grasshoppers on roads and in private lawns and gardens. Severe grasshopper outbreaks are neither aesthetically or physically pleasing to most people.

Users of Public Lands

There is a remote chance that users of public lands might see a reduction in the amount of wildlife in public and private lands surrounding farms that participated in the program. The increased use of insecticides may result in poisoning or repellency of animals. Hunting and fishing is an important past time in Montana so reductions of either fish or wildlife species due to increased insecticide use would have an adverse effect on socioeconomics. Additional grasshopper control on farm land adjacent to public lands may reduce the numbers of grasshoppers on these lands making them more desirable to the public during years of grasshopper outbreaks.

Rural Life

This program might both benefit and detract from the quality of life in rural areas. An increased use of insecticides might decrease quality of life in rural communities because of insecticide drift and the potential for contamination of water and private property. The reduction in the numbers of grasshoppers by spraying under this program would have a positive affect on the rural communities, both from an aesthetic and physical standpoint. Knowledge of the damage that grasshoppers are inflicting on producers crops and the effect that might have on the local economy may be a source of stress for members of rural communities.

Alternative B1. c) Economic Impacts

Producer Income

Inability to control grasshoppers during an infestation year may result in severe crop loss and resultant economic hardship. State and county assistance in the purchase of insecticides may help reduce total money loss due to grasshopper damage. However, few producers across the state actually benefit from the program. Of an approximate 20,000 farm units, a maximum of 1,246 (6.2%), ever participated in one year. Producers experiencing severe grasshopper or other insect infestations in counties not participating in the program receive no state assistance. Ranch owners whose land does not qualify to be treated under the APHIS program have no recourse to assistance from the state. Producers that participated in the program would benefit by having a portion of one insecticide bill paid. However, as stated in Chapter 3, this program reached only a limited number of producers and benefits received were small.

State Revenues

The state may have received some increased revenues to balance the money spent on the program if the program increased producers net returns. Producers sprayed grasshoppers 1-5 times during the growing season and the state paid a maximum of 1/3 of the bill. Thus a calculation of increased state revenues (based on what the state paid) would have to be given as a fraction of any yield saved by the program.

Short Term Versus Long Term Productivity

This program might increase short term productivity by helping producers reduce the severity of grasshoppers during an infestation. This type of program would have little or no effect on widespread grasshopper populations. Increased insecticide use may have a negative effect on long term productivity. There is no evidence available to suggest that continuous insecticide use will decrease the occurrence of future grasshopper infestations. Increased use of insecticides may worsen the current problem by reducing beneficial organisms in producers fields resulting in the development of secondary pests that are destructive to crops thus reducing productivity.

Rural Economics

At best this program might improve rural economics in the short run if it did help save producers crops. Local tax revenues might increase and producers might spend more locally. Growth or at least maintenance of local economies throughout the state is dependent on agriculture. The actual effect of this program on the rural economies is impossible to determine. Actual effects of the program on these factors would have been very small and realized by only several counties.

Alternative B1. d) Cumulative Effects

Determination of the combined effects of this program on the environment is impossible as there was no monitoring of the short or long term impacts of the program. One may speculate that the overall impact of this program on the state would be relatively small as the program covered such a limited geographic area and changed very little of producers normal control tactics. The program may have helped a small number of producers reduce their total production costs during a grasshopper infestation; however, many producers experiencing similar grasshopper outbreaks received nothing.

The impact of this program on the environment would vary each year depending on the site, the number of acres infested, and number of producers that participate in the program. If the program convinced producers to spray insecticides that otherwise would not have, then the program would have the effect of increasing the amount of insecticides that are present in the environment. The incremental increase in insecticide use combined with normal use of all pesticides may have an adverse effect on the environment. The extent of this impact would be

site specific and would most likely be negligible compared to current use of pesticides. Thus the impact of the current program is limited economic benefit with the potential for additional contamination of the environment.

Alternative B2: Elimination of State Emergency Program

This alternative would eliminate the current emergency program and involve no emergency expenditure of state resources for grasshopper control. However, the MDA entomologist would continue to perform the duties of surveying counties to determine the severity of grasshopper outbreaks and other related duties. This program would possibly reduce insecticide use in several counties during outbreak years.

The Governors emergency funds previously used for assisting in grasshopper control would be available for other domestic emergencies. This alternative may decrease the impacts of the current program on the environment, but may increase economic and socioeconomic impacts. This alternative does not affect the counties emergency response program in which individual counties may declare a grasshopper emergency and act on it accordingly.

It is assumed that this alternative will eliminate the incremental increase in insecticide use imposed by the current program. It is possible that this would result in instances of reduced productivity at some sites. Reduced control may also mean greater numbers of grasshoppers the following season.

Alternative B2. a) Environmental Impacts

Air and Water Quality

A study of the extent of impact of this alternative on the environment must be based on comparison to the current program. This is difficult to determine because so few producers ever took part in the current program in any one year. However, in the short run this program would slightly reduce the total amount of insecticides used in the state during an infestation and thus reduce potential water and air quality hazards. One less application of an insecticide in a sensitive area might reduce the possible occurrence of water contamination. This would also decrease the likelihood of contamination of aquatic organisms. Decreased insecticide use might improve air quality in these areas. Farms that rely on state monies for additional grasshopper control might have increased

grasshopper populations on their lands. These grasshoppers may migrate to neighbors fields resulting in increased insecticide use on farms with sufficient financial resources to control them. Increased insecticide use in a limited geographic area might have a greater impact on water quality than insecticide use spread out over a large area.

On a localized basis, increased soil exposure due to decreased grasshopper control might worsen air quality due to increased wind erosion of soil. However, grasshoppers tend to leave a large quantity of litter on the soil surface which may inhibit wind erosion (Onsager 1987). Water quality in the eastern 2/3 of the state is affected by total suspended solids and increased sedimentation due to increased soil erosion could affect water quality. Aquatic organisms would also be affected by increased suspended solids.

Soil and Vegetation

This program would have little or no direct effect on soil or vegetation as no action is being taken. However, the fact that grasshopper infestations might not be controlled may have a notable effect on vegetation and soil on both cropland and neighboring non-cropland. Depending on the palatability of a plant species to a species of grasshopper, the presence of that plant might be affected by the presence of grasshoppers in large numbers. Some rare vegetative species that inhabit non-cropland or rangeland could be affected. Soils might be affected by reduced grasshopper control and thus increased exposure. This might increase wind and water erosion of soil.

Wildlife

The slight decrease in insecticide use by not running the current program should be beneficial to wildlife in the short run. Birds, insects, and rodents are the most likely to benefit from reduced insecticide use. The actual reduction in insecticide use by not running the program would probably have the greatest effect on non-target insects. Preservation of beneficial insects may further reduce the need for insecticides which would increase the benefits gained by all non-target organisms. Birds would be less likely to consume insects containing insecticide residues or to contact spray drift. This would also be true for mammals. If larger numbers of grasshoppers exist under this program, wildlife that consume grasshoppers would benefit from a larger food source.

The effect of grasshopper populations on wildlife has never really been documented. Grasshopper infestations on cropland might compete

with wildlife to some extent if large populations were to migrate from fields to rangeland or preserve land following ripening or harvest. Some birds and mammals consume grasshoppers as a major part of their diet during summer months (Lavigne and Pfadt 1966).

Human Health

Contamination of the human environment might be decreased by eliminating the current program. Likelihood of direct or indirect contact with insecticides would be reduced if this alternative actually reduced the use of insecticides.

Alternative B2. b) Socioeconomic Impacts

General Public

The general public in Montana might benefit by saving the state emergency funds for a different emergency. Decreased insecticide use by elimination of the current program would be slight but would have a positive effect on the general public. There would be less worry of insecticide contamination of the environment. Elimination of the current program may reduce adverse feelings of the public towards the state for using emergency funds to assist producers in paying their grasshopper control bill. Large populations of grasshoppers are neither aesthetically or physically pleasing to humans, reduced insecticide control of these pests may increase their numbers in human communities.

Users of Public Lands

Users of public lands might benefit from reduced insecticide use but might also be less inclined to use public lands that are affected by grasshoppers. The reduction in insecticide use by eliminating the current program might have a beneficial effect on the health and amount of wildlife on public lands and thus may benefit outdoor recreation and tourism. Though tourism is somewhat of a minor issue in the eastern half of the state, hunting and fishing are very important. This program would have no impact on the archaeological or paleontological resources of Montana.

Rural Life

Rural communities might initially benefit from decreased occurrence of insecticide drift, reduced likelihood of water contamination, and contamination of private property. These communities may suffer in the long run if local productivity were reduced. Reduced farm productivity in communities that rely on local agriculture to survive are hurt by decreased spending by local producers which in turn reduces the total revenues earned by all members of the community.

Alternative B2. c) Economic Impacts

Producer Income

Elimination of any state assistance during grasshopper infestations would directly affect the state, some counties and limited number of producers. Producers that could not control grasshoppers without state assistance would receive no income from the state and county program and would experience lower income from reduced crop yields. However, very few producers in any one year ever received money from the state.

State and County Revenues

The State and participating counties would save those emergency funds otherwise used in the emergency grasshopper program. The losses incurred by producers are ultimately incurred by the state, counties, and federal government in the form of reduced cash receipts and increased insurance payments. However, the amount of revenues lost by not helping producers control grasshopper infestations would be relatively small as the number of producers affected by the program are few.

Short Term Versus Long Term Productivity

Short term productivity might decline under this alternative. If individual producers are unable to control grasshoppers during an infestation, their productivity will be lower than otherwise. The current program reduces some producer's overall insecticide costs, this alternative would remove that benefit.

Long term productivity would possibly increase if fewer beneficial organisms were affected by insecticide use under the program. This might also reduce the likelihood of grasshoppers developing resistance to the currently used insecticides. However, the small decrease in

insecticide use that would be realized with this alternative would have a minor effect on beneficial organisms.

Rural Economics

If producer income declined locally due to elimination of the program the immediate county economics might be affected. The impact of this alternative on county revenues state wide would be negligible. Reduced insecticide use might result in reduced drift. Apiaries, organic crops, and livestock would be less likely to come in direct contact with insecticides.

Alternative B2.d) Cumulative Effects

A small environmental benefit and a limited individual producer cost are the two most tangible effects of this alternative. No initial increase in insecticide use would exist with this program. A major concern of this alternative is the effect on individual producers and rural communities during years of grasshopper infestations. However, only a limited number of producers benefit from the current emergency program and those that benefit receive very little.

If sufficient control is not implemented, possible effects include: reduced producer income, reduced rural spending, reduced county revenues, reduced ability to support recreation, increased potential of another severe grasshopper outbreak (depending on seasonal climatic conditions), and possible short term increased potential of soil erosion.

Eliminating the current program might reduce insecticide use by a small increment and thus may reduce the likelihood of contamination of water and private property. This would also reduce the combined effect of insecticides used in the emergency program with general pesticide use within the region.

Alternative B3: Targeting State Assistance

This alternative gives state assistance to producers who are experiencing severe grasshopper infestations and choose to use control practices that are regarded as having low environmental impact. The program would be funded much the same as the current program, the state will cost share with producers and counties on one treatment of cropland. The state would pay a maximum of 1/3 of producers costs. Infestations must be widespread within a geographic region determined by MDA scouts.

Funds would be available to producers experiencing grasshopper infestations who then decide to control them with low impact measures. These measures would include, but are not limited to:

a) insecticide baits (i.e. carbaryl bait)
b) biological control
c) spot treatment of fields with products of lower toxicity (i.e. Tox Category II and III Appendix D, Table D-3).

Spot treatment refers to control of grasshoppers in a limited area thus forcing intensive identification of dense populations of grasshoppers and treatment only on those parts of the fields. This should reduce treatment of large blocks of cropland which have not been intensely monitored.

The purpose of giving state assistance for use of these control methods during grasshopper infestations is to promote the use of control measures that have lower environmental impact yet sufficiently control grasshoppers. Producers may receive payments only if they are within an area deemed infested by the MDA. The program would be updated each year to allow for the addition or elimination of the accepted control methods. The efficacy of the control alternatives will be observed and recorded by the MDA.

The MDA would not conduct any of the actual treatments but would be a source of information and a channel for funds for those experiencing severe grasshopper infestations. The MDA would have to hire field survey personnel to complete the duties outlined in this alternative. The funds for these personnel would have to come from an alternative source. The incremental increase in land treated for grasshopper control would likely be similar to that of the current program but the methods of control would have less environmental impact.

There would probably be less insecticide use in this program as compared to the current program. If the state promotes the use of these control approaches, the likelihood of environmental contamination might decline.

Producers would gain from better monitoring of fields and receipt of financial assistance. Initially producers might observe similar or slightly less impressive results than they achieve with highly toxic insecticides; however, use of these control strategies might result in long term grasshopper control by maintaining higher levels of beneficial organisms which aid in the control of grasshoppers as well as a number of other pests. Reduced use of insecticides may reduce the likelihood of the development of resistance to currently used insecticides.

Alternative B3. a) Environmental Impacts

Air and Water Quality

This program might have some additional impact on water quality and air quality beyond that incurred by non-state assisted grasshopper control. However, the use of baits and limited use of class II and III compounds has less potential for affecting water quality than current use of the available compounds. The likelihood of stream contamination by any of these treatments is fairly low. Insecticide baits could be applied by aircraft; however, liquid insecticide use would be limited to spot control which would reduce aerial application of liquid insecticides. This would reduce the impact that the current program has on air quality. There is a slight potential for air contamination due to volatilization but as stated earlier this factor has little impact on air quality in open wheat fields.

This alternative is less likely to affect aquatic organisms than the current program. The use of the given control strategies may even reduce the total volume of insecticides used in the state if producers have success with these strategies. If such a program proves to be effective in controlling grasshoppers, other producers might use a similar approach, further reducing the possibility of surface water contamination.

Soil and Vegetation

This program would have little impact on vegetation and may have less adverse impact on soil organisms than the current program. The insecticides used under this program have the potential to affect soil organisms; however, the approach of spot control or use of baits greatly decreases the potential impact of the program. During an infestation baits are generally consumed within an hour of application thus reducing the likelihood of leaching of carbaryl into the soil (Mukerji et al. 1981).

Wildlife

Wildlife would benefit from this program. Reduction in aerial treatments and elimination of class I compounds from the program would reduce the potential for hazardous exposure for upland game bird, waterfowl, and song bird to insecticides. Mammals would also be less likely to contact insecticides than with the current program. Limiting the use of insecticides to trap strips, baits, and spraying of limited areas of dense grasshopper populations should greatly reduce the potential impacts on wildlife.

There should be fewer non-target insect kills under this alternative than with the current program. The potential for honey bee and leafcutter bee kills would decline if there were a reduction in the potential for insecticide drift. This program should reduce the widespread kills of beneficial organisms that normally help keep grasshoppers and other insect pests in control. This effect would further reduce the need for insecticidal control of insect pests. If sufficient control is not achieved in this program, producers may retreat with any method or product they choose. This would completely eliminate the positive effects of this program.

Human Health

Human health would also benefit from this program over the current program. This program may slightly increase insecticide use over that of no program; however, it promotes control approaches with less environmental impact than that of the current program.

The primary health risk of this alternative is that producer application of insecticides would increase if aerial application to control grasshoppers decreased. Most grasshopper control is achieved by aerial application of insecticides by certified commercial applicators who understand the dangers of insecticides. However, aerial application of insecticides has the greatest potential for contacting individuals via drift. The toxicity of the compounds that would be available for use in this alternative would be less than the two products used most in the current program (parathion and carbofuran).

Alternative B3. b) Socioeconomic Impacts

General Public

Some potential for environmental contamination would still exist with this alternative, but to a lesser degree than with the current program. The general public would benefit from reduced insecticide drift from aerial application of insecticides. This would reduce contamination of private property and the threat of human and domestic animal exposure to insecticides during periods of grasshopper outbreaks. The control of grasshoppers with state assistance should be more extensive under this program and might give better long term control than the current program. Producers who do not choose to treat their fields with the available control strategies would gain no direct benefit from the program. Sale of insecticides not available in the program might decline.

This alternative increases the work required by the state to assist in grasshopper control. This program raises additional problems of identifying what products are suitable for the program.

Users of Public Lands

Users of public lands would benefit from a possible reduction in wildlife and fish contamination which may occur presently. Public lands that neighbor producers lands who have chosen to take part in this hypothetical state program might have populations of fish and wildlife that are less likely to be contaminated with insecticides as compared to lands which neighbor fields receiving conventional treatment. People recreating in these areas would also be less likely to come in direct contact with insecticide drift. Individuals consuming game might be less likely to be exposed to insecticide residues.

Rural Life

The general affect of this alternative on rural communities would be quite similar to that of the current program. These communities might be affected by changes in both producer spending and insecticide sales and service. There might be a slight reduction in the likelihood of water or private property contamination under this alternative.

Alternative B3. c) Economic Impacts

Producer Income

Producers should be able to achieve reasonable control of grasshoppers by using the methods outlined in this alternative. Producers that enter the program should receive approximately the same level of assistance from the state as they did under the current program. Some of the available controls would cost more than the insecticides currently registered. However, treatments may be applied to a smaller acreage and should allow for more long term grasshopper control than insecticides used in the current program. Producer costs might decline in the long run if the methods employed have less impact on beneficial organisms.

If producers were not able to achieve sufficient control with the methods available in this program larger net losses might be incurred as compared to the current program. Producers might not be able to afford a second control treatment or producers might treat their fields again with a treatment not available in the program.

State and County Revenues

If producers receive yields similar to those in the current program, the state should realize cash receipts similar to the current program. Decreased use of insecticides during a grasshopper infestation might actually result in reduced requirement for insecticides in the years following the infestation. This would have a positive effect on state and local revenues, but might result in a loss to the private pesticide dealers and distributors.

Short Term Versus Long Term Productivity

Productivity should not be compromised by this alternative. Long term productivity may be better with this alternative than with the current program. Fewer beneficial organisms would be killed by controlling grasshoppers thus reducing the need for insecticides in the long run. However, the actual amount of insecticides used under both this alternative and the current program would be relatively small compared to the total amounts used regardless of the program.

Rural Economics

Depending on the efficacy of control under this alternative, rural economics should benefit from this program. Productivity and returns should be similar to the current program in the short run and may even reduce long term producer spending on insecticides. Rural communities would benefit from a greater propensity for producers to spend as compared to having no program. These communities might realize a general increase in economic stability.

Other groups that would gain economically from this program would be organic producers and apiarists that are affected by insecticide drift. Hunting and fishing may be more desirable in areas where the likelihood of animal contamination is lower. This would have a positive effect on rural and state economics. Aerial applicators and local insecticide sales might be slightly lower with this alternative as compared to the current program.

Alternative B3. d) Cumulative Effects

The primary impact of this alternative would be to reduce use of insecticides that can be harmful to the environment and human health. This alternative has fewer options for control of grasshoppers during an

infestation than the current program. However, use of control methods outlined above might allow for the survival and build up of beneficial organisms that keep grasshoppers and other potential insect pests in check. If grasshoppers do not appear to be sufficiently controlled by the given methods and producers apply synthetic insecticides following the program; the result is greater total application of insecticides and loss of the positive effects of the program. Most producers treated their fields more than once during the season to control grasshoppers during the years of the emergency program. Thus it is likely that growers will retreat regardless of initial application.

This alternative might reduce the amount of insecticides used for grasshopper control in the emergency program. The control measures should have less impact on the environment and may give long term control. Fish, wildlife, air quality, water quality, and human health would be less likely to be affected by the combined effects of this alternative and insecticides use outside the program as compared to the current program.

C. Non-Emergency Alternatives Considered

During years when no severe widespread grasshopper outbreaks (emergency infestations) occur, grasshoppers can still seriously impact cropland and rangeland. Hewitt and Onsager (1983) reported that grasshoppers annually destroy at least 20% of available forage on rangeland in the west. During these years actions could be taken to both reduce the likelihood of severe widespread grasshopper outbreaks and control grasshoppers in localized outbreaks. The following alternatives include those mitigating actions that might reduce the need for emergency declaration for control of grasshoppers.

Alternative C1: No Action

The state would not become involved in any assistance, education, or cost share functions above that which the state presently conducts. The state currently holds or participates in a number of training programs for insecticide application, integrated pest management, and environmental safety. Currently no temporary scouts are employed by the state and all insect monitoring is being performed by the MDA entomologist. The MDA previously employed five seasonal field scouts to accomplish this

large task, but these were eliminated by budget reductions in 1986. The loss of these scouts has made effective insect surveillance impossible and led to a late infestation detection in 1986. Late insect detection may result in increased insecticide use.

This alternative requires no additional funding and has no additional short term impact on the environment as no action is being employed. This alternative would have no direct impact on the environment, any impacts would be due to producers conventional control of grasshoppers with no direction or participation from the state. This program would have no mitigating effect on the occurrence of severe widespread grasshopper outbreaks. It is possible that continued conventional grasshopper control (use of synthetic insecticides) would reduce numbers of beneficial organisms and result in the eventual or gradual development of resistance by grasshoppers to registered insecticides.

Alternative C1. a) Environmental Impacts

Air and Water Quality

The environment would suffer no additional damage above that which is presently occurring. There is some potential for long term effects of continued use of synthetic insecticides by a large number of producers. Insecticides are not a major pollutant of water resources in Montana. Organophosphate insecticides are generally non-persistence in water (Table 5), thus long term impact of such insecticides on water quality is difficult to determine. A gradual decline in fish populations or health of populations due to undetected contamination may occur in localized areas.

Soil and Vegetation

There would be no direct impact of this alternative on soil or vegetation. Continued application of synthetic insecticides to control grasshoppers and other pests may lead to temporary damage of populations of soil organisms and vegetative species that rely on insect pollination. Synthetic insecticides have been in use for over 40 years, but the long term effects of these compounds on soil organisms are still not fully understood.

Wildlife

This alternative would have no additional direct adverse effect on wildlife. The amount of insecticides currently being used may have a negative effect on wildlife. A discussion of the potential impacts of grasshopper control with synthetic insecticides is given in Chapter 5. Birds, mammals, and non-target insects all have the potential to be exposed to insecticide sprays during grasshopper control. However, such impacts would not be increased by this alternative.

Human Health

Human health would not be affected any more than it is presently. Long term affects may include continued direct and indirect contact with insecticides with the potential for long term health problems if insecticide use increases. Improper handling of insecticides has the greatest potential effect on human health. If long term insecticide use increased, there will be a greater probability of spills, accidents, and improper handling. This alternative would have no short term impacts on human health.

Alternative C1. b) Socioeconomic Impacts

General Public

This alternative would have little or no short term adverse effects on general public or rural communities. Long term impacts due to a gradual increase in insecticide use may include increased likelihood of contamination of private property.

Short term benefits that might be gained by this program include a greater amount of state money available for social or economic development programs. In the long run, the number of jobs for insecticide applicators and sales people might increase.

Users of Public Lands

This program would have no direct adverse impacts on users of public lands. Wildlife and those people observing or hunting wildlife would not be affected by this program. However, current levels of insecticide use has a documented impact on some wildlife populations (Chapter 5) which this program would not reduce.

Rural Life

People living in rural communities would neither lose or benefit from this program. The occurrence of grasshopper infestations would not be lessened under this alternative nor would contamination of the rural environment. Levels of insecticide use surrounding rural communities would not change.

Alternative C1. c) Economic Impacts

Producer Income

Few economic benefits would be gained by this alternative. No long term benefits would be gained by producers. Producers would receive no additional training or assistance from the MDA during a period when many other states are studying and implementing long term insect control strategies via integrated pest management and sustainable agriculture techniques. Producers would not be assisted in an attempt to reduce the occurrence or severity of grasshopper infestations.

State and County Revenues

County and state revenues would not be directly affected by this alternative. Short term gains include the fact that state money would not be spent on a non-emergency grasshopper program or general IPM program. Continued use of conventional insect control might reduce the ability of Montana producers to compete with other states in small grain production if input costs become too high.

The states economy might initially benefit from using those funds not spent on agricultural programs. Monies could be spent on social, economic, or industrial development programs. However, Montana's economy is heavily dependent on agriculture which is a very stable economic base. Recreation and tourism are another major source of state cash receipts, but this aspect of the economy is very dependent on the economic well being of the nation. If the future brings higher transportation costs, inflation, and reduction in mean annual salary, certainly the amount of money spent on travel and recreation will decline as well. Grain crops are a staple portion of the worlds diet and Montana has proven itself as a producer of high quality grain. Grain will always be a desired commodity regardless of national or international economics.

Short Term Versus Long Term Productivity

Producers would gain nothing from this alternative in the short run, productivity would neither increase or decrease. To compete nationally and internationally, Montana producers would have to develop modern agricultural techniques without the assistance of the MDA. Though the MDA is not currently involved in an IPM program, several other states have implemented IPM and sustainable agriculture programs to increase the farm productivity within their state. Montana producers should receive the same type of assistance that their counter parts receive if they are to produce competitively.

Rural Economics

If one considers the current status of rural economics stable and well off, this program offers no change. However, farm economics are changing and many counties are contending with declining populations and declining income. This downward circle will ultimately lead to isolated population centers in the eastern portion of the state and the deterioration of rural communities and a way of life. These communities rely on agriculture as their economic base and it is the duty of state government to assist in promoting the economic stability of the state as a whole and not only those portions which are presently more economically stable.

Alternative C1. d) Cumulative Effects

This program would have no direct effect on the environment, state, county, or producer economics. The indirect impacts of insufficient grasshopper control would have a negative effect on rural economics. If this is combined with other natural disasters or infestations these communities may lose a portion of their economic base.

Indirect long term effects on the environment would be due to a hypothetical, gradual increase in insecticide use. If such an increase did occur and was accompanied by an increase in fungicide and herbicide use; fish, wildlife, and human health could affected by increased pesticide exposure.

Alternative C2: State Assisted IPM Development Program

Under this alternative the MDA and the MSUES would educate and assist producers in the implementation of integrated pest management (IPM) strategies on any crop in any region of the state. Integrated Pest Management is an optimization of pest control in an ecologically and economically sound manner that is accomplished by the coordinated use of multiple tactics to assure stable crop production and maintain pest damage below economic injury level while minimizing hazards to humans, animals, and the environment (Dover 1985). Such a program is composed of the following basic elements:

-focuses on management of the cropping system rather than a pest;

-is preventive and long-term in nature;

-uses alternatives that are least toxic to humans and the environment;

-uses synthetic pesticides following determination that the pest has reached the economic threshold;

-assumes that it is desirable to reduce dependence on pesticides;

-a problem must exceed "the acceptable level of damage" and then be verified prior to taking action;

-requires monitoring of the results of the action;

-requires a supporting program of applied research;

-requires continuous program modification and evaluation.

These are the foundations upon which a complete IPM strategy is based. The success of an IPM program relies on a commitment to these elements. The program which is being considered by the MDA attempts to provide a route by which producers throughout the state may follow these guidelines and achieve the goals of an IPM program.

The MDA has directed the establishment of several IPM programs including the Alfalfa Seed IPM and Potato IPM programs (Bain 1982,

Bain 1978). The Montana State University Extension Service (MSUES) currently performs a small grains Integrated Crop and Pest Management (ICPM) program which has been available to a very limited number of producers (Lindh et al. 1987). The USDA-APHIS is beginning a study of the feasibility of a rangeland grasshopper IPM program for the control of grasshoppers on federal land and private rangeland (USDA-APHIS 1987). However, to this date, the theory and practice of IPM has been available to only a limited number of crop producers in Montana. The MDA would work in cooperation with the MSUES and attempt to help producers implement an IPM program.

The MDA would hire 10 to 12 seasonal field survey personnel (scouts) who would perform efficient and complete insect surveillance as well as rodent, weed, and disease monitoring for the proposed IPM program.

In many cases, IPM programs have been adopted out of necessity. This occurs when pesticide use continues to increase as insects, weeds, and diseases begin to develop resistance to those pesticides being used. Beneficial organisms are suppressed beyond their ability to aid in the control of pests and those organisms that are ordinarily non-destructive become serious crop pests (secondary pests). Crops begin to fail and net returns are greatly reduced as pesticide bills consume much of the producers costs.

This type of scenario has not occurred with small grain production in Montana; however, the potential exists and the process may be underway. An excellent example of this occurrence is cotton production in Texas in the 1970's (Adkisson et al. 1981). Cotton producers were forced to implement an IPM program when conventional (insecticide) control became ineffective against insecticide resistant pests. Within four years of implementation the IPM program was demonstrated to give net returns on cotton of $161/acre as compared to $33/acre with conventional control (Adkisson et al. 1981). Insecticide use on cotton in Texas was estimated to have declined from 19.3 million pounds annually to 2.3 million pounds. Producers savings from this decline alone would be extremely high.

Montana has the option to adopt an IPM program prior to it becoming a necessity. Such a program should not only increase producers returns but may also decrease some of the long term likelihood of contamination of the environment. Though the majority of crop production in Montana is devoted to small grains, the MSUES small grains ICPM program is forced by limited resources to remain a pilot program available to only a limited number of producers. Funding for this program would have to come from a combination of general or special funding, funding of the

Crop Insect Detection Act (MCA 80-7-502), and perhaps an insecticide surcharge. Other possible sources of funding include APHIS project grants and EPA research grants. It must be recognized that with the current economic condition in Montana, that total funding for and IPM program is highly unlikely. The following discussion assumes that an IPM program is possible; however, the reader should realize that state funding for such a program does not currently exist.

The MDA would serve primarily as a catalyst for initiation of an IPM program which would ultimately be run by producers. This program would begin with the hiring of a minimum of 10 - 12 field scouts. Scouts would have the minimum requirement of junior college status in an applicable agricultural science. Scouts would work in cooperation with the MSUES scouts and conduct disease, insect, and weed surveys in their respective regions. Scouts would also have the responsibility of assisting in training sessions, documenting possible control tactics through observation, and documentation of successful control tactics used in the program. Appendix F outlines an idealistic approach of an IPM program. Though this is written as a standard IPM program, monitoring and control of grasshoppers would be inherent under such a program.

The goal of this program would be to reduce producers input costs and increase long term productivity on any crop in the state. Insecticides will be used only after the economic threshold is reached, thus insecticide use may be reduced. Cultural and biological techniques would not give the striking, immediate results that are seen with insecticide use, but if run properly reduced input costs would outweigh any reduction in yield. If the program proved beneficial to those producers involved in the program it would attract other producers thus further decrease statewide pesticide use. However, management strategies are not readily available for all crops grown in Montana and experts on pest management in various crops may have to be imported. Best results from the program would not be realized for at least 3 years following implementation.

Alternative C2. a) Environmental Impacts

Air and Water Quality

If this program is well accepted and functioned properly, widespread insecticide use may decline after a number of years. This would have a positive effect on the environment. Grasshopper control should not be forsaken by this program, but rather the increased surveillance would increase efficiency of control.

Air quality and water quality should benefit from this alternative in the long run due to a decline in pesticide use. The likelihood of pesticide contamination of drinking water should decline as well as the likelihood of fish kills due to insecticide runoff. If the program did not meet producers needs (in terms of net returns) and they decide to return to conventional control the environment would be no worse off than previous. The use of insecticides for grasshopper control and aerial application of insecticides might decline under this alternative. If this program did reduce the occurrence or severity of grasshopper infestations, this alternative would reduce the problems posed by the current program as well as conventional control not covered under the emergency program.

Soil and Vegetation

Since this alternative is designed as a complete IPM program, it would have direct and indirect effects on soil and vegetation. An IPM program does not exclude the use of pesticides but would rely on them only as needed. This may reduce long term the use of herbicides, fungicides, and insecticides. If herbicide use declines under this alternative, there would be less potential for herbicide drift or runoff damage of crops or vegetation. Over time, this alternative may reduce the amount of pesticides that have an adverse effect on soil organisms. This alternative poses no foreseeable negative impacts on soil or vegetation.

Wildlife

Wildlife would certainly benefit from implementation of a IPM development program. The extent of the state affected by this program would most likely be far greater than that of the current emergency program and would cause less environmental impact. There may be a general decline in insecticide use. This would decrease the effect on non-target insects and ultimately decrease the need for control of secondary pests. The number of bee kills due to insecticide drift would also decrease. The IPM program would produce no foreseeable negative effects on wildlife as compared to the current program. The use of IPM strategies may produce a more natural habitat than cropland under conventional practice. A decrease in insecticide use might stimulate population growth of organisms whose populations have been affected by conventional insect control.

Human Health

Human health could also benefit from this IPM program. Producers and the general public would have less direct and indirect contact with insecticides as well as other pesticides. However, an IPM program requires that field scouts and produces spend considerable time monitoring fields for pest populations. This may increase human exposure to pesticides especially if label reentry intervals are not observed or environmental conditions result in prolonged activity of the pesticide (see Chapter 6).

Alternative C2. b) Socioeconomic Impacts

General Public

The general public may benefit from a large scale IPM program. Reduced long term pesticide use would reduce exposure of humans to pesticides.

An IPM program would create many problems for state government. Those who feel that government should not spend more money on agricultural programs would be vocal against such a program. The MDA would have to increase its staff to accommodate such a program which under the current economic condition is not likely to be supported.

Users of Public Lands

Users of public lands would also benefit from reduced insecticide use. These users might experience reduced likelihood of contact with insecticides and might observe an increase in the diversity of insect species. There might be reduced exposure of fish, mammals, and birds to pesticides which reduces indirect human exposure via consumption of game species. Users of public lands would also benefit from a reduction in the occurrence and severity of grasshopper infestations if the IPM program function properly.

Rural Life

Rural communities would also benefit such a program. In the long run these communities would benefit from increased quality of life as there would be a reduction in the potential for insecticide exposure. Though a large scale IPM program might reduce synthetic insecticide sales it might also increase hiring of private consultants and sales of

biological insecticides in the long run. However, this was not observed to be true during the Alfalfa Seed or Potato IPM programs.

Fields that are under IPM are generally less attractive to the human eye than with conventional control. A field clean of weeds and uniform in stand is somewhat of a status symbol for producers across the nation. Giving up the pristine look of a conventionally treated field for increased net returns is a question to contend. Watching insects or weeds ruin the appearance of ones field while waiting for the pest to reach the given economic threshold is not easy for many producers.

Alternative C2. c) Economic Impacts

Producer Income

Economic benefits should be gained under this program if it functioned properly. An IPM program should reduce the input costs associated with conventional practices which in turn may offset yield reductions due to damage inflicted by pest populations below the economic threshold. Producers who are committed to the program and follow its guidelines should benefit from increased net returns in the long run. However, producers would have to allow at least 3 years for the program to operate at full potential. This has been difficult for many producers to accept in past IPM programs directed by the MDA.

State and County Revenues

An increase in net returns would benefit the state as well as producers. If Montana producers were to achieve increased net returns, they would be that much more able to compete with producers from other states. Direct and indirect tax earnings from the sale and application of synthetic insecticides might decrease. Only a limited number of companies in Montana actually produce synthetic insecticides and by far the majority of those products used in the state are produced by out-of-state firms.

The major economic burden of this program would rest with the state. The annual cost of this program would be approximately $200,000 to $250,000. The costs include training sessions, research funding, the hiring of an IPM specialist, a lab technician, and field scouts. Though this cost is similar to one year of the emergency program, the emergency program is not implemented on an annual basis. Funding of the IPM program would have a higher direct cost to the state than the emergency program, but may ultimately increase state cash receipts.

Short Term Versus Long Term Productivity

One of the main benefits of an IPM program is that it considers long term productivity. Short term productivity should not be greatly compromised by this program. However, as stated earlier, producers must allow at least 3 years for an IPM program to reach operating potential. IPM is also a dynamic approach to agriculture, it is designed to be flexible with changes in climate, pest problems, and cropping systems.

Rural Economics

Rural communities would benefit from increased spending by local producers if the program did indeed increase net returns. This has a positive effect on growth and development of such communities. A financially healthier community increases the amount that a community may spend on programs that make the area more attractive to further development by both industrial and recreational interests. Cash receipts from organic farmers, apiarists, alfalfa seed producers, and even livestock owners could potentially increase from a reduction in the use of insecticides.

Alternative C2. d) Cumulative Effects

This program has the potential to reach more people and have deeper impact than any of the emergency programs. The cost of such an IPM program in a given year would be similar to the average amount paid into a year of the current emergency program. However, the current program assisted an average of only 860 producers per year (3.6% of Montana's producers). Though an IPM program would not preclude the occurrence of a grasshopper infestation, it may reduce the impact and likelihood of one.

Reduced insecticide use is desirable to both the general public and producers alike. Any net additional impact of this program would be positive. Producers, their families, neighboring communities, and fish and wildlife should experience less exposure to pesticides over time. However, in the MDA's experience with IPM programs many producers did not actually reduce their insecticide use and many would ignore economic threshold values if they felt that their crop was in peril. Such actions would eliminate many positive effects of an IPM program.

Reduction in bee kills and potential fish and wildlife exposure would possibly relieve some pressure on further pesticide restrictions. Continuous use of insecticides may lead to further insecticide recalls and

restrictions. Improper handling of some pesticides has led to their removal from market.

The proposed IPM program may reduce the health risks faced by humans, domestic animals, and wildlife. Effective pest control with reduced pesticide use would result in a healthier environment that would benefit wildlife and humans alike.

Problems associated with this alternative include; the high annual cost, lack of management information for all crops, and the difficulty of disseminating information across the whole state. The resources available in Montana may be too limited to effectively implement such a program.

Alternative C3: Research and Demonstration of Control Alternatives

Though much research has been performed on alternative strategies of grasshopper control, producers primarily control grasshoppers with synthetic insecticides. This alternative is designed to provide development and applied field demonstration of alternative grasshopper control strategies. Funding for research and demonstrations will be provided by the state and performed by the Montana State University System, the MSUES, USDA Rangeland Insect Lab (RIL), and other qualified organizations that apply for assistance. Control strategies that will be field tested are based upon previous research that show some promise for use in Montana agriculture. The methods would be designed to give effective, inexpensive, long term control of grasshoppers while having minimal impact on the environment. Demonstrations of this type have been performed by staff at the MDA; however, lack of funding and staff has limited its success (Gillespie and Pond 1987).

Funding for this program would come from the general or special funds and possibly from federal research grants such as USDA-APHIS project grants. The legislature would have to fund this program at an annual cost of at least $100,000.

Presently, Nosema locustae is the only biological control agent registered for grasshopper control with the EPA. Many other organisms have been identified as plausible commercial control agents; however, they are all still in developmental stages and have to be tested further. Though Nosema has been proven as a long term grasshopper control agent it is not effective under an emergency situation, because it is unable to give rapid, high mortality rates of grasshoppers (Onsager 1988, Johnson 1987).

Several viable alternatives could be tested by the MDA, research institutions, or private groups under state support. This applied research must be conducted on farms or on experiment stations. An advisory panel of producers, researchers, government officials, and other interested individuals would be selected by the state and university system to determine what proposed experiments would be funded. Experiments which could be initiated under this program must conform to the following set of criteria:

1. Site selection; experiment must be performed on sites characteristic of cultivated land in Montana and must avoid wetlands, waterways, and other sensitive areas if the proposed experiment has the potential for adverse effects on the environment.

2. Environmental impact; experimental technique must use an environmentally sound approach which limits impacts on the environment.

3. Cost effective; proposed experiments must be economically feasible for implementation by producers (unless the experiment is in an early stage and shows promise, but economics are not certain yet).

4. Efficacy; proposed research must have substantiating laboratory, greenhouse, and field plot efficacy data which demonstrate significant grasshopper control potential.

Examples of experiments that might be funded by the state include; planting date experiments (USDA Undated), varietal tests (Olfert et al. 1988, McBean and Platt 1951, Jacobson and Farsted 1941), combination baits of Nosema locustae and carbaryl (Hewitt and Onsager 1983), biological agents such as Nosema locustae, Beauveria bassiana, Verticillium lecanii, parasitic and predatory insects (Onsager 1988, Marcandier and Khachatorians 1987, Johnson et al. 1988, Rees 1986), and trap strips (Olfert 1986). The USDA rangeland insect lab has partially developed an "expert system" which assists ranchers in determining an economic threshold for grasshopper infestations and suggests methods of control at a given stage (Berry et al. 1983, Kemp et al. 1988). Though the present system has been designed for rangeland use, researchers have suggested that adaptation to cropland is possible. This use would then be tested for its efficacy under field conditions.

It should be noted that the Montana State University System has spent millions of dollars on grasshopper control research over the last 80 years. Thus, the likelihood of getting immediate feedback from such a program

must be questioned. The idea behind this alternative is to assist in the field testing of promising studies or to retest methods not used since the onset of synthetic insecticides.

This alternative is designed to produce long term grasshopper control options. This program would give little or no return to the state during the first several growing seasons that it is implemented; however, it would not have any negative effects either. Producers may be able to implement some of the tested control techniques within one or two years of implementation of the program. Each of the tested techniques will be designed for low financial input and reduced use of insecticides. If the techniques are effective and well accepted this program should help producers control grasshoppers with minimal impact on the environment. Ultimately the producers should gain better long term control of grasshoppers and perhaps reduced likelihood of grasshopper infestations.

Alternative C3. a) Environmental Impacts

Air and Water Quality

This alternative would have little or no impact on the environment within the first season that it is implemented. Long term impacts should be positive by attempting to reduce producers dependence on synthetic insecticides. This should have a long term positive effect on air and water quality if the techniques are effective.

Some of the techniques will include the use of low toxicity insecticides. Since the experiments would include no aerial or large area spraying of synthetic insecticides the likelihood of water or air contamination by direct contact would be very low. Waterways and sensitive areas will be avoided during site selection for insecticide experiments.

Fish and other aquatic organisms might benefit from the eventual implementation of grasshopper control approaches that have minimal impact on the environment. There is no way to determine how many producers will implement these control strategies, but any decrease in insecticide use has the potential to be beneficial to these organisms.

Soil and Vegetation

The land area affected by this alternative would initially be very small, confined to the experimental site. Most of suggested control approaches would have no potential for soil contamination. The program should actually reduce the long term impact of insecticide use on soil and vegetation.

Wildlife

Wildlife would also benefit from a hypothetical long term decrease in synthetic insecticide use. Birds and non-target insects would benefit the most from reduced aerial application of insecticides. The research program itself would have little effect on wildlife because each approach uses biological control or low toxicity insecticides over a small area. This program would not increase insecticide use and thus would not increase the current impact of insecticide use on wildlife.

Human Health

Human health would not be adversely affected by this program. If producers begin to implement these control approaches, they will have less exposure to insecticides as compared to the use of conventional control tactics. These approaches would also reduce the amount of insecticide drift which may affect rural communities during grasshopper outbreaks. The direct impact of this program on human health would be limited to the use of insecticides in the experimental field plots. The long term impact has the potential to be positive.

Alternative C3. b) Socioeconomic Impacts

General Public

This alternative should benefit most groups in the long run, but have little immediate effect. The use of state monies for this program might eliminate funding for other social or economic programs. The actual project would benefit the state in the long run if it did reduce insecticide use and reduce the occurrence of widespread grasshopper infestations.

The general public might benefit from reduced contact with insecticides. If producers began to implement these control strategies there might be less need for aerial spraying of liquid insecticides. This would reduce insecticide drift which may contaminate water and private property.

Users of Public Lands

Users of public lands would not be directly affected by this alternative. If the research is successful, benefits that might be realized with this alternative include; decreased insecticide drift to public lands, decreased likelihood of fish and wildlife contamination, and possibly reduced occurrence of widespread grasshopper infestations on public lands.

Rural Life

This alternative would have a minor affect on rural life. The actual research would have no foreseeable effect. Long term benefits might include reduced likelihood of water or private land contamination by insecticide drift and possibly a reduction in the occurrence or severity of grasshopper infestations.

Alternative C3. c) Economic Impacts

Producer Income

The impact of this program on producer economics would not be felt initially. The long term effects of this program should be positive if the control tactics studied in this program are effective and are accepted by producers. Producers inputs might eventually be less than that of conventional control and the likelihood of a devastating grasshopper infestation might be reduced.

State and County Revenues

The appropriation of monies for this alternative would be a cost to the state initially, but long term monetary benefits may also be gained. The use of state money for this alternative reduces the amount available for funding of industrial and recreational development in the state. In the long run this may hurt Montana's economy. However, agriculture is one of Montana's most reliable sources of income. The geographical and environmental setting of Montana has historically inhibited its industrial development. Recreational development is extremely dependent on the economic well being of the nation. Thus agricultural interests must be protected. This alternative may increase long term agricultural cash receipts by a small margin and may reduce the need for use of emergency funds for grasshopper control.

Short Term Versus Long Term Productivity

This alternative would have no affect on short term productivity. Long term productivity would be directly affected by this alternative if the control approaches proved to be effective. These control measures are designed for long term control of grasshoppers and should not put pressure on development of resistance to insecticides by pest insects.

Rural Economics

If producers incomes increase with this alternative, then rural communities would benefit from increased producer spending which would act to stimulate general economic health in rural communities. Possible losses incurred by this program include; decreased insecticide sales, production or reformulation, and service (application). However, grasshopper infestations do not occur consistently, thus the total impact of reduced grasshopper-insecticide sales would have little impact on this portion of rural economics.

Alternative C3. d) Cumulative Effects

If this alternative is carried out and producers are able to achieve safe effective control of grasshoppers by the demonstrated strategies, generally most would benefit. The program might benefit producers by giving them other control options that may allow for long term control of grasshoppers. There should be no adverse cumulative effects on economics or the environment. The state might also gain from reduced environmental impact from continued use of synthetic insecticides and the potential future costs that might occur.

Alternative C4. Roadside Grasshopper Control

The purpose of this alternative is to control grasshoppers on road margins in the state of Montana in an attempt to reduce this source of grasshopper populations. Producers throughout the state have suggested that a major source of grasshopper problems initiates on state owned road right-of-ways where no grasshopper control is taking place. The state would participate in a 1/3 cost share program with interested counties in an attempt to decrease the total grasshopper problem within the state.

Road right-of-ways make up approximately 158,000 acres of land area in rural Montana (MT Highway Dept 1988). Much of the road right-of-ways are adjacent to cultivated fields or rangeland and serve as an excellent site for grasshopper oviposition. By controlling grasshoppers on these lands during non-infestation years producers might help mitigate the occurrence of grasshopper infestations. The state would carry out assistance to affected areas during infestation or non-infestation years. The state and participating counties would make funds available for grasshopper control on roadsides using biological control agents during non-emergency years and would include the use of carbaryl baits, or

equivalent low toxicity baits, during severe widespread infestations. The program may be summarized as follows:

1) MDA would work in cooperation with the MSUES and would hire field scouts whose duties would include general insect surveillance and determination of grasshopper densities along roadsides.

2) During non-infestation years, scouts would determine whether road margins adjacent to cropland would require grasshopper control.

3) MDA would make money available to affected counties on a cost share basis for the application of Nosema baits. This should allow for the build up of Nosema in these areas and help reduce the likelihood of an infestation in these areas in following years.

4) If scouts determine the presence of widespread grasshopper infestations in several counties, the state would offer the affected counties financial assistance for the spreading of carbaryl baits on infested areas. Baits would not be applied in areas deemed sensitive to bait application.

5) The decision to conduct a program or not would be determined by the county.

6) Scouts would return to treated areas to determine the efficacy of the control measures.

7) A program summary would be compiled by the MDA following each season to determine the efficacy of the program.

Using available biological insecticides during non-emergency years should help maintain low grasshopper populations while having minimal impact on the environment. Synthetic insecticides would be used only during widespread grasshopper outbreaks.

Efficient scouting is a necessity to achieve sufficient grasshopper control on these sites and reduce the likelihood of an emergency. Each scout would cover a region of the state and complete general insect surveillance as well as survey density of grasshoppers on roadsides. The scouts would respond to and survey reports of dense grasshoppers populations on these public lands. Funding of this alternative would come from the general or special funds, funding made available through the Crop Insect Detection Act, or perhaps a insecticide tax surcharge. At least 2/3 of the funding for the actual purchase of insecticides would be

paid by individual counties. Funding would have to come from a county general fund. The counties would also be responsible for the application of the baits. The total cost of the program would depend on the severity and distribution of grasshoppers and would have to include funding for at least 10 field scouts.

The state would promote the maintenance of dense (not an over grazed condition) canopies of grass on roadsides as such conditions inhibit grasshopper development and survival (Anderson 1964). Unless a county is experiencing a severe widespread grasshopper outbreak, the state would give assistance to only those purchasing biological baits. Presently this is limited to the use of Nosema locustae. Nosema locustae has been proven to give about 50% control of grasshoppers on range and is most effective when applied prior to peak 3rd instar (Onsager 1988). If the baits are applied regularly or annually to problem areas, sufficient control may be achieved to eliminate roadsides as a source of grasshopper populations during periods of widespread grasshopper outbreaks. However, in a roadside study by Johnson and Henry (1988), Nosema bait resulted in a grasshopper mortality rate of only 30% during the initial year of the study.

If counties are experiencing severe outbreaks of grasshoppers the MDA would assist in the purchase of carbaryl baits for roadside control. Carbaryl bait has been demonstrated to give rapid, effective knock down of grasshoppers (Onsager 1978). If available, baits impregnated with both Nosema locustae and carbaryl would also be considered for roadside control.

In this program county personnel or applicators hired by the counties would be responsible for the application of the baits. The MDA would not take the action of controlling grasshoppers. State funded control of grasshoppers on road right-of ways may decrease the numbers of grasshoppers moving into cropland and rangeland. The program might also decrease the likelihood of an emergency situation.

Programs similar to this have been run by several counties in Montana with positive results. State assistance would simply make such a program more attractive or attainable to more counties. This program could help increase the productivity and returns on Montana farms as well as reduce the short term intense use of insecticides necessary to control a grasshopper infestations. The insecticides that would be used under the program are either very selective or exhibit low toxicity.

Alternative C4. a) Environmental Impacts

Air and Water Quality

The state would only give assistance for the use of Nosema locustae baits primarily in non-emergency years. Other pending bio-control agents such as entomopox viruses (Street 1987) may be acceptable under emergency conditions. Nosema baits would have no foreseeable effects on the environment; however, because of their time and control limitations they cannot be used under an emergency situation. Carbaryl baits are somewhat selective in that they primarily affect those organisms that consume baits. The formulation of carbaryl bait ranges from 2.0% to 20% active ingredient which would have little effect on organisms that are not consuming the baits. Grasshoppers have also been observed to consume all the applied baits within a matter of hours (Mukerji et al. 1981). Thus this program should have no impact on air quality and may actually act to improve it in the long run if it reduced the need for intensive insecticide use to control grasshoppers during severe outbreaks.

It is unlikely that water quality will decline under this program. According to application rates, adsorption coefficients, and leaching potentials (Tables 6 and 7) the likelihood of surface or groundwater contamination at levels in excess of tolerance limits set by the EPA will not likely occur. However, if spring runoff and rains coincide with carbaryl bait applications to roadside ditches, there would be some potential for runoff and thus water contamination. This alternative has the potential to help reduce current impact on water quality in the long run by reducing the need for intensive use of synthetic insecticides during grasshopper outbreaks.

Soil and Vegetation

This alternative should have little or no impact on soil or vegetation. If grasshoppers are in large numbers, the insecticide baits that would be used might have a slight adverse effect on soil organisms. Baits are consumed rapidly by grasshoppers and pose no threat to pollinating insects. This alternative may actually be beneficial to those plant species that are damaged by grasshopper infestations. This would take place on lands not normally affected by agricultural chemicals.

Wildlife

This alternative should have little or no effect on wildlife as no synthetic insecticidal sprays are used and synthetic insecticide baits will be used only during years of severe grasshopper outbreaks. In these cases consumption of the baits is the primary route by which animals would be affected. Dermal contact with the baits should have little or no affect on non-target organisms. For example, a generic tick and flea collar worn around the neck of domestic dogs may be 9% carbaryl (a.i.) as compared to the soil applied 2.0 to 20% carbaryl baits that have been proven effective in grasshopper control (Onsager 1980).

Insecticide use in the state might decrease both during emergency and non-emergency years if grasshopper movement from road margins declines. If this were the case the impact of the program on wildlife as a whole would be positive.

The use of low toxicity baits on roadsides has the potential adversely affect resident birds. Roadsides are one of the few remaining suitable habitats for a variety of birds. The use of insecticide baits on these road margins may greatly affect bird populations that otherwise might not be treated with agricultural insecticides. This is a particular hazard for ground nesting birds such as the meadowlark, lark bunting, and vesper sparrows which frequently inhabit roadsides. Unfortunately, grasshopper treatments might take place during a time span when these birds are present. The American Kestrel, which consumes grasshoppers during summer months, frequently perches on power lines that run along many highways. To avoid long term impacts of such a program, a sample population of those birds potentially affected may have to be studied and monitored to determine if there will be impacts. Cost of such monitoring would not be covered by the suggested funding allotment.

The likelihood of bird poisoning with carbaryl bait is relatively low (Schafer 1983), but consumption of many contaminated grasshoppers may lead to chronic poisoning of wildlife. However, producer applications of insecticides near roadsides may have a greater effect on bird populations than the suggested application of carbaryl baits. This alternative would presumably reduce the need for grasshopper control on private land.

Human Health

This program would little or no short term effect on human health and most likely would reduce potential long term health affects. The suggested control measures are of no or low toxicity to humans. However, county applicators would be working with the carbaryl baits

during infestations. This program might reduce the need for producers to control grasshoppers thus reducing the number of humans coming in contact with insecticides from ground or aerial spraying. Persons walking or riding bikes on roads which are being treated with the bran baits may come in contact with particulate matter from the applied baits, but such exposure would be minimal.

Alternative C4. b) Socioeconomic Impacts

General Public

This alternative may benefit or hinder different groups within the state. The program would take money from possible social programs and direct it toward what is primarily an agricultural cause. The program may affect some avian fauna along roadsides. If the program decreased the need for producer application of insecticides, the general public might benefit from reduced insecticide drift. The number of grasshoppers on state roads would also be reduced.

To implement this program the MDA would have to increase its staff and funding. This program creates some problems for the state in that it would overburden the understaffed MDA. The MDA would be responsible for implementation of the program and select the use of compounds accepted for use in the program. Carbaryl bait is currently the only synthetic insecticide bait registered for grasshopper control. Since this decision is based on documented toxicity, federal registration, and environmental hazard, it should be a legally defendable decision.

Users of Public Lands

Users of public lands should not be affected by the use of low toxicity baits on roadsides. If insecticide use did decline under this alternative, users of public land would benefit from reduced likelihood of insecticide drift to public lands and possibly increased health of wildlife populations. The major concern of this program is its effect on bird species that populate roadsides. This alternative may affect avian fauna that is desirable to many users of public lands.

Persons walking, jogging, or bicycling along roadsides during treatment periods may be affected by the insecticides. The biological baits should have no potential adverse health effects, but particulates from the synthetic insecticide baits may result in human inhalation, consumption, or dermal exposure. However, the dose that might be encountered would be very small. These same groups may benefit from reduced need for

producer use of insecticide sprays near these same roadsides during a grasshopper infestation.

Rural Life

Rural communities would benefit from reduced grasshopper problems that originate from roadsides. If the program reduced the occurrence of grasshopper infestations and thus reduced use of insecticides, rural communities would benefit from reduced insecticide drift that may contaminate private properties. The program should reduce grasshoppers on roadsides which may limit grasshopper infestations of lawns, gardens and roadsides. Reduced numbers of grasshoppers is also a physical and aesthetic benefit to some people.

Alternative C4. c) Economic Impacts

Producer Income

In the long run this program may reduce regional grasshopper problems by helping keep numbers down in non-infestation years. If the program did reduce grasshopper numbers; producer yields and returns should increase especially for lands that otherwise receive no grasshopper treatment. The program should reduce the severity and occurrence of grasshopper infestations which would benefit producers.

State and County Revenues

If the program helped decrease the likelihood of grasshopper infestations the state as a whole would benefit. County and state cash receipts might increase with increased productivity on farms. Whether the increased cash receipts would be enough to offset the cost of the program, depends on the extent of the grasshopper outbreak and how much of the state's 158,000 acres of road right-of-way must be covered in any one year. Some counties have conducted bait spreading on road margins in the past without state assistance. This program would possibly make this treatment available to a greater number of counties.

Short Term Versus Long Term Productivity

This alternative has the potential to increase both short term and long term productivity. Crop productivity might benefit reduced grasshopper populations under both infestation and non-infestation conditions. Build

up of Nosema locustae in these sites of common oviposition may generally reduce grasshopper numbers in these areas.

Rural Economics

If producers experienced increased returns, rural communities would benefit from increased spending. This might aid in maintaining a more stable local economy that can better support both industrial and recreational development. Reduced insecticide use is an economic benefit to those who are affected by insecticide applications (apiarists, alfalfa seed producers, and organic farmers).

Alternative C4. d) Cumulative Effects

This alternative should reduce the severity of grasshopper infestations in Montana while having minimal impact on the environment. Producer yields and returns might be positively affected by this alternative which would have a series of positive effects on the state. However, this program would result in a large increase in state expenditures.

During years of infestations, when carbaryl baits are in use, this program may adversely affect birds that inhabit roadsides. However, if this program decreased the need for producer application of insecticide sprays to field margins that boarder roadways, there may actually be a decreased impact on bird species that inhabit roadsides. Long term effects might include decreased need for insecticide control of grasshoppers by producers and perhaps reduced impact on wildlife that inhabit cropland.

Alternative C5: Integrated Grasshopper Management

Integrated grasshopper management (IGM) is a possible approach to a complex problem. Lack of funding and the diversity of crops affected by grasshopper infestations make it extremely difficult for the MDA to assist in the implementation of effective grasshopper control with an IPM approach for all cropland in Montana. However, alternative approaches to grasshopper control must be considered if Montana producers are to achieve safe effective and long term control of grasshoppers. Those crops affected by grasshoppers in Montana include alfalfa, sugar beets, potatoes, corn, beans, and small grains. To serve all producers and yet

maintain a reasonable budget, the MDA cannot simply enter into an expansion of the MSUES small grains ICPM program, or easily budget for the previous IPM development alternative. An IGM program might allow the MDA in cooperation with the MSUES to assist in effective monitoring, training, research, and management of cropland grasshoppers in Montana. The IGM program would be composed of the following basic elements.

-Based on management rather than eradication of grasshoppers.

-The approach would be preventative and long-term in nature.

-Would promote the use of alternatives that are least toxic to humans and the environment.

-Would use synthetic insecticides only after grasshoppers reach an economic threshold.

-Would include monitoring of the results of the action.

-Would promote education and dissemination of information with respect to grasshopper outbreaks and successful control.

-Would include a support program of applied research.

-The program requires continuous modification and evaluation.

Funding for the program would have to come from either the general or special funds, an insecticide sales surcharge, or partially from federal insecticide use reduction grants. The MDA's tentative approach to IGM would be as follows.

Field scouts would be hired following academic winter quarter and would work through mid-August. Early scouting is a necessary part of any IPM control strategy. Field scouts will also perform general insect surveillance. The MDA would hold training sessions on alternative approaches to grasshopper control stressing the use of preventative cultural practices. The basic grasshopper control alternatives are presented in Table 12.

The MDA would help fund applied research that supports and leads to continued development of the IGM program. Research would be

based on; recent developments from universities and research institutions, previous knowledge abandoned with the onset of synthetic insecticides, and observations by producers and scouts in the monitoring program. Research would be performed by qualified public or private institutions both on farm and on state or federal experiment stations.

Table 12. Alternatives for grasshopper control under an IPM program.

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1) Early seeding of spring planted crops.

2) Cultivation of soil to destroy or bury eggs and eliminate food source for young nymphs.

3) Trap strips; 30 foot wide strips of a spring grain bordered by bare soil. The strips of grain are treated for grasshopper control once the grain is heavily infested or late planting of a 30 foot wide strip of barley treated with a preplant systemic insecticide.

4) Choice of a cultivar that is tolerant or resistant to grasshopper damage (studies must be run for Montana cultivars).

5) Use of biological controls Nosema locustae, parasitic and predatory insects, and pending biocontrol agents.

6) Use of chemical insecticides or repellents.

Insect surveillance would begin in mid-April. The monitoring would consist of general insect surveillance while concentrating on grasshopper surveillance, response to reported grasshopper outbreaks, surveillance of natural predators of grasshoppers, monitoring of impact of insecticide use on wildlife, and monitoring of the efficacy of the implemented treatments. The scouts would be responsible for assisting producers in monitoring their own fields and recording the results of the implemented program.

Scouts would be stationed regionally for general insect surveillance. If grasshopper outbreaks occur within a limited region of the state, two or more scouts would then concentrate on that particular location to assist in monitoring and advising. The MDA would favor the use of media to announce the occurrence of grasshopper outbreaks and the potential strategies to control them.

The program would be initiated through the MDA and the MDA would assume ultimate responsibility for the program. The MDA would appoint an 8 member advisory panel that consists of producers, Extension personnel, MDA staff, university personnel, and other qualified individuals. The panel would monitor, evaluate, and revise the program on a regular basis. Ultimately, producers would take complete control of the program and the MDA would serve an advisorial role and a statewide coordination role.

This program would have to be conducted every year regardless of the extent of grasshopper problems. Ideally the IGM program would reduce long term input costs and thus increase producer's net returns. The program should also become more effective with time as the program develops and adapts to the needs of producers. Integrated Grasshopper Management is designed to give a proactive approach to managing grasshoppers to reduce their numbers and avoid reaching the economic threshold. This is beneficial to human health, environment, and crop production.

Alternative C5. a) Environmental Impacts

Air and Water Quality

Under this alternative the use of insecticides to control grasshoppers would most likely decline. Both air and water quality would be under less threat of contamination with this program as compared to the current program. By definition, this program would use insecticides only once the pests reach the economic threshold and would promote the use of compounds that will have minimal impact on the environment (based on individual sites). Aerial application of insecticides to control grasshoppers might decline under this alternative which would have a positive affect on air quality.

The likelihood of water contamination might decline from present. Fish would thus be less likely to encounter pesticide contaminated waters with this program. Reducing insecticide use may benefit desirable fish such as trout by not favoring less desirable fish such as carp. Reduction of insecticide use may also benefit populations of fish prey. This program should reduce the likelihood of insecticide poisoning of non-target insects that are a major food source for desirable species of fish such as trout.

Soil and Vegetation

This alternative introduces no additional impact on soil or vegetation over that presently encountered. Long term impacts of this alternative on soil organisms or insects beneficial to vegetative species adjacent to producers fields would be favorable. Use of insecticides in this program may have some short term affects on soil organisms.

Wildlife

Wildlife would be less likely to come in contact with insecticides if this alternative reduced the occurrence of widespread grasshopper outbreaks. This alternative may reduce insecticide use on a yearly basis as well as during years of severe widespread grasshopper outbreaks. A reduction in use of insecticide sprays may reduce the impact on non-target insects and thus the need for insecticide use.

Birds and mammals might benefit both directly and indirectly from the IGM program. A reduction in the use of insecticide sprays would reduce exposure of wildlife to insecticides. Fewer contaminated grasshoppers would be consumed by birds or mammals, and fewer birds and mammals would come in direct contact with insecticides.

Human Health

In general, human health may benefit by implementation of an IGM program as compared to no action. The likelihood of grasshopper infestations and the annual impact of grasshoppers may decline with this alternative. The IGM program may reduce both short and long term insecticide use if the program reduced the severity of grasshopper outbreaks. This would reduce the potential deterioration of air and water quality that directly affect human health. This may reduce the occurrence of chronic and acute poisoning due to insecticides.

Alternative C5. b) Socioeconomic Impacts

General Public

The general public would benefit from an IGM program as compared to the current program. People would benefit from a less contaminated environment. This program might reduce the need for emergency declarations and thus increase the funds available for other emergencies

and simply reduce state expenditures for that year. However, the money needed to fund this alternative would reduce the monies available for social or economic programs that are funded by the state. This program may develop several problems for the state. The MDA would have to restructure and hire a number of personnel. The funding for such a program would be quite difficult at this time. Producers could possibly assist in funding such a program, but this probably would not happen unless grasshopper populations were always economically damaging.

Users of Public Lands

Users of public lands would benefit from reduced insecticide use on emergency and non-emergency years. The program might lead to reduced need for aerial application of insecticides. Reduced insecticide drift may result in less impact on wildlife that inhabit public lands. This alternative has the potential to increase the recreational attractiveness of areas normally affected by grasshopper control.

Rural Life

Rural communities should benefit from this program. This alternative should reduce the use of insecticides to control grasshoppers. This would reduce the likelihood of water or private property contamination. The program may reduce the livelihood of local insecticide sales and service which might ultimately lead to a loss of jobs. The program also opens opportunities for other positions in field scouting, consulting, and biological control sales and service.

Use of an IGM program requires that grasshoppers reach a predetermined economic threshold prior to using insecticide control. Though IGM might increase producers returns, they must accept the presence of threatening levels of grasshoppers regardless of their past response to lower grasshopper numbers. This is a difficult point for many to overcome. Producers must also grapple with the fact that grasshoppers are not a necessarily a serious problem every year. Most producers are strictly reactive to grasshopper problems. Convincing producers to use preventative measures based on population predictions might be quite difficult.

Alternative C5. c) Economic Impacts

Producer Income

Several economic benefits might be gained by implementation of the IGM program. The IGM alternative may reduce producers input costs for the control of grasshoppers and thus increase their returns. However, this IGM alternative has not been field proven for grasshopper control. It uses methods one might implement in an IPM program to control grasshoppers, but it does not take into account what producers are doing about other pests. The use of insecticides to control other pests may result in loss of beneficial organisms which are important for the optimization of IGM.

State and County Revenues

The state would benefit from increased tax revenues if producers were able increase their net returns by implementing IGM. Tax revenues from the sale and application of synthetic insecticides would possibly decrease, but this might be offset by an increase in the sale and application of biologicals. The state would fund the IGM program, one year of which would cost less than an average one year expenditure on the current emergency program. However, this program would be conducted every year. This program may ultimately lead to the hiring of consultants and field scouts once producers take over the program.

Short Term Versus Long Term Productivity

This alternative has the potential to improve short term and long term productivity. The program would be available to a larger number of producers than the current program and would be designed to maximize producers returns. However, any IPM alternative cannot be expected to operate up to its full potential for the first three years and will never give the stunning grasshopper mortality of heavy synthetic insecticide use. Long term productivity is a goal of IGM, thus this approach to pest management is designed to give long term pest control rather than rapid mortality.

Rural Economics

The IGM program would decrease any impact that grasshopper control with synthetic insecticides might have on businesses such as organic farming and bee keeping. This might increase cash returns of these businesses which in turn may increase state tax returns.

Rural communities might benefit from increased spending by producers. Increases in wheat productivity has a direct impact on rural economics. The extent of impact of IGM on rural development is unknown; however, it can be surmised that the overall affect of this alternative would be dependent on the occurrence and extent of grasshopper outbreaks and the efficiency with which the IGM program works.

Alternative C5. d) Cumulative Effects

The primary impact of this alternative is via potential reduction in grasshopper infestations resulting in a potential reduction in insecticide use. The program may increase producers returns which has a positive effect on the state economy.

Though this program would not preclude the occurrence of a grasshopper infestation, it has the potential to reduce the impact and likelihood of one. The program would result in a small incremental reduction in total insecticide use during grasshopper infestations and during non-infestation years. This reduction in insecticide use may reduce the potential for environmental contamination and human contact with insecticides.

The primary problem with IGM is that it is not a proven program for grasshopper control. State government would be under great criticism if it spent large sums of money on a program which only partially achieved its goals or proved to be ineffective in achieving long term grasshopper control. However, the individual control methods suggested in this alternative have been demonstrated in some areas to reduce the crop damage inflicted by grasshoppers. This coupled with sensible use of insecticides which give sufficient grasshopper control; inflict minimal impact on the environment; and reduce the likelihood of insects developing resistance to currently used insecticides, would all be positive impacts of the program. The state could accomplish such a program only if producers, researchers, industry, and governmental officials are able to work cooperatively. This would benefit each group in the long run.

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APPENDICES

Apendix A. Insecticides Registered for Grasshopper Control.

Table A-1 Insecticides registered for grasshopper control.

Insecticide	Crop						
	Small Grains	Alfalfa	Pasture Range	Corn	Potatoes	Sugar Beets	Turf Ornmtls
Acephate			X				
Azinphos-methyl		X					
Carbaryl	X	X	X	X	X	X	X
Carbofuran	X	Y					
Chlorpyrifos		X		X			X
Diazinon		X	X	X	X	X	X
Dimethoate		X		X	X		
Disulfoton	X						
Fenvalerate				X	X		
Malathion	X	X	X	X		X	Z
Methiocarb							
Methyl Parathion	Z	Z		X		X	
Mevinphos		X			X		
Naled		X	X			X	
Nosema locustae	X	X	X	X	X	X	X
Parathion	X	X	X		X	X	
Phorate	X	X					

X -- Registered for control of grasshoppers
Y -- 1986 and 1987 only
Z -- Mixed with other compounds

Table A-1. Insecticides registered for grasshopper control (cont.).

Insecticide	Crop						
	Beans	Safflower	Sunflower	Peas	Lentils	Field Margins	Garden
Acephate	X					X	
Azinphos-methyl							
Carbaryl	X	X	X	X			X
Carbofuran							
Chlorpyrifos			X				
Diazinon				X			
Dimethoate	X						
Disulfoton							
Fenvalerate	X		X	X		X	
Malathion		X					
Methiocarb							X
Methyl Parathion		X	X				
Mevinphos				X			
Naled	X						
Nosema locustae	X	X	X	X	X		X
Parathion		X		X			
Phorate							

X -- Registered for control of grasshoppers
Y -- 1986 and 1987 only
Z -- Mixed with other compounds

Appendix B. State and County Statistics for the 1985, 1986, and 1987 Grasshopper Emergency Program.

Table B-1. Year, # land owners, total acres sprayed, % of county land, total state participation, state participation. per acre, and average cost of application per producer for the grasshopper emergency program.

County	Year	# Land Owners	Tot Acres Sprayed	Tot Co Acre	% Co Land	Tot St Part $	St Part $/Acre	Av Cost/a Prod $
Carter	1985	48	14,147	2,120	0.67	12,913	0.91	3.87
	1986	56	26,494	"	1.25	14,280	0.54	3.89
Daniels	1986	167	111,638	924	12.09	56,245	0.50	3.36
	1987	118	78,233	"	8.47	28,542	0.36	2.59
Golden Valley	1986	21	18,052	753	2.40	8,253	0.46	3.05
Judith Basin	1985	47	10,255	1,203	0.85	15,770	1.54	5.73
Petrolium	1986	23	13,593	1,059	1.28	9,842	0.72	4.83
	1987	23	25,934	"	2.45	9,695	0.37	2.65
Pondera	1985	136	39,346	1,053	3.74	43,480	1.11	4.75
Prairie	1985	195	26,505	1,107	2.39	11,704	0.44	3.52
Richland	1986	243	123,125	1,331	9.25	69,038	0.56	3.73
Roosevelt	1986	234	113,987	1,526	7.47	57,176	0.50	3.34
Sheridan	1985	281	116,684	1,084	10.76	112,021	0.96	2.88
	1986	377	243,329	"	22.44	100,152	0.41	2.74
	1987	332	174,756	"	16.12	98,490	0.56	4.00
Treasure	1986	43	24,758[a]	630	3.34	12,733	0.51	3.43
	1987	35	7,924	"	2.24	9,425	0.68	4.85
Wibaux	1985	54	19,509	570	3.42	19,508	1.00	3.82
	1986	82	48,346	"	8.49	22,281	0.46	3.07
Yellowstone	1987	159	47,736[b]	1,691	2.40	32,848	0.69	4.88
TOTAL		2,574	1,273,520	22,522	----	711,854	----	----
AVERAGE		129	63,676	1,126	6.02	37,466	0.66	3.79

Table B-2. State total and average statistics for the 1985, 86, and 87 grasshopper emergency program.

County	Year	# Land Owners	Tot Acres Sprayed	Tot Co Acre	% Co Land	Tot St Part.	St Part /Acre	AvgCost/A Producers
STATE TOTAL								
	1985	661	226,418	93,200	0.24	215,395	0.99	4.10
	1986	1,246	721,318	"	0.77	350,000	0.48	3.49
	1987	667	334,583	"	0.19	175,000	0.52	3.79
AVERAGE		858	427,440	------	0.40	26,798	0.66	3.79
THREE YEAR TOTAL		2,574	1,282,319	------	---	740,395	---	---

Appendix C. Rules and Contracts of the State Grasshopper Emergency Program

Appendix C-1

State of Montana

Proclamation

WHEREAS, grasshoppers exist in such numbers that they are destroying, substantially damaging, or threatening to destroy agricultural crops; and

WHEREAS, the presence of grasshoppers throughout numerous counties in the State of Montana constitutes a serious insect pest infestation; and

WHEREAS, the effective control of a grasshopper infestation requires remedial action prior to grasshoppers reaching full adulthood; and

WHEREAS, pursuant to section 10-3-103(6) an "emergency" means the imminent threat of a disaster causing immediate peril to life or property which timely action can avert or minimize; and

WHEREAS, pursuant to section 10-3-103(3) a "disaster" means the occurrence or imminent threat of widespread or severe damage, injury or loss of life, or property, resulting from a natural cause requiring emergency action to avert or minimize infestations; and

WHEREAS, the existence of a serious insect pest infestation constitutes an emernency under Title 10, Chapter 3, and Title 80, Chapter 7, Part 5, MCA, and

WHEREAS, Title 80, Chapter 7, Part 5, MCA, provides a mechanism for the equitable distribution of funds to counties who participate in an insect pest control program; and

WHEREAS, a proclamation of emergency activates the emergency response and disaster preparation aspects of the State disaster and emergency plan and authorizes the Governor to expend from the general fund to meet the contingencies and needs arising from an emergency.

NOW, THEREFORE, I, TED SCHWINDEN, Governor of the State of Montana, pursuant to the authority vested in me as Governor under the Constitution of the State of Montana and Title 10, Chapter 3, MCA, do hereby declare that a serious insect pest infestation constituting an emergency exists on croplands used for the production of food and forage, including the headlands, ditches, and rights-of-way adjacent to such land in many counties throughout the State of Montana, and that

This proclamation does not extend to rangelands; and that

This proclamation of emergency shall expire within 20 days of its issuance or the termination of the emergency, whichever occurs earlier.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the GREAT SEAL OF THE STATE OF MONTANA to be affixed. DONE at the City of Helena, the Capital, this 11th day of June, in the year of our LORD, one thousand nine hundred and 85.

TED SCHWINDEN
Governor of Montana

ATTEST

JIM WALTERMIRE
Secretary of State

Appendix C-2

BEFORE THE DEPARTMENT OF AGRICULTURE
OF THE STATE OF MONTANA

In the matter of the adoption of emergency rules pertaining to the Cropland Insect Detection and Spraying Program	))))	NOTICE OF THE ADOPTION OF EMERGENCY RULES PERTAINING TO THE CROPLAND INSECT AND SPRAYING PROGRAM

TO: All interested Persons.

1. On June 20, 1986 Governor Schwinden declared a state of emergency regarding a grasshopper infestation in the state of Montana. This declaration utilizes Title 80, Chapter 7, Part 5, Montana Code Annotated (MCA), to provide a mechanism for the equitable distribution of funds to counties that participate in an insect pest control program.

The Department of Agriculture has determined that grasshoppers exist in such numbers that they are destroying, substantially damaging, or threatening to destroy agricultural crops.

The department must adopt the following rules immediately, without prior notice or hearing, in order to ensure equity in the distribution of the funds to participating counties. The department finds that an imminent peril to the public welfare requires adoption of these rules.

2. The text of the rules is as follows:

RULE I DECLARATION OF INFESTATION (1) The department shall make a declaration of infestation in a county before that county may participate in the cropland spraying program with the state.

(2) This declaration shall be based upon sampling standards acceptable to the department that demonstrate that grasshoppers exist in sufficient numbers so as to cause an economic impact on the crops in the county.

AUTH: 80-7-507, MCA IMP: 80-7-502, MCA

RULE II MANAGEMENT AGREEMENT (1) The department and county may enter into a crop insect management agreement upon the county's demonstration that it meets all necessary requirements for participation in the program, including any requirement specified for the use of the state's available funding.

(2) The department shall enter into an agreement with each participating county which shall include the following provisions:

(a) The target pest is grasshoppers.

(b) Specify that the county shall obligate the expenditure of the 2 mill levy required by 10-3-405, MCA for this program prior to participation by the state.

(3) Specify that all applicators participating in the program must use federal/state registered pesticides specifically approved for grasshopper control.

(4) Specify the time for which all applicator operations must be completed in order to be part of the program.

Appendix C-2 (cont.)

(5) Specify the maximum dollar amount per acre of the state's share which shall not exceed $1.25 per acre of the acres that may qualify for state financial participation.

(6) Specify the deadline for parties to submit claims for reimbursement of payments.

(7) Designate the person(s) administering the program for the county.

(8) Specify any other provisions necessary to fulfill the requirements of the program.

AUTH: 80-7-507, MCA IMP: 80-7-503, 80-7-504, MCA

RULE III CONTRACT DATES (1) The agreement with the county shall specify that all contracts for purchasing and/or applying the pesticide must be made on or before July 9 and all applications shall be completed on or before July 19 of the year.

AUTH: 80-7-507, MCA IMP: 80-7-503, 80-7-504, MCA

RULE IV LANDOWNER APPLICATION OF PESTICIDES (1) For the purpose of these rules, the definition of landowner includes the person responsible for the crop.

(2) In the event the county elects to have the landowner conduct the application of pesticides or have the landowner contract to have the pesticides applied on his lands, then:

(a) The landowner must comply with all requirements of these rules and he must pay for all chemical and application costs incurred on or before September 1 of the year.

(b) The landowner must:

(i) Submit proof of payment for the pesticide and/or the applicator services demonstrating that the application occurred on or before July 19 and that the contract for these services occurred on or before July 9.

(ii) Verify by affidavit that the application was made if the landowner applied the pesticide.

(iii) Specify the number of acres sprayed.

(iv) Specify the type of pesticide applied and if it was mixed with any other nontarget pesticide.

(v) Submit all the claims to the county on or before September 1.

(3) In the event the landowner fails to meet the requirements of these rules, then any application of pesticides to his land shall be considered outside of the program and he shall be ineligible for reimbursement.

AUTH: 80-7-507, MCA IMP: 80-7-503, 80-7-504, MCA

RULE V DETERMINATION OF THE STATE'S PAYMENT TO THE COUNTY (1) The county shall submit to the department on or before October 1 the number of acres sprayed in that county, number of participating landowners, and total costs submitted under the program.

(2) The department shall determine the total number of acres sprayed in the state under the program.

Appendix C-2 (cont.)

(3) The state shall pay each participating county a pro rata share, as stipulated in these rules, from the emergency appropriation fund. The state's financial participation in the program with each county that has qualified is limited to an amount up to 1/3 of the total cost of the qualified acres in that county. However, the state participation on a per acre cost basis shall not exceed $1.25, nor shall the state's participation exceed $350,000 for all the treated acres within the qualified counties. The county pro rata share of the $350,000 shall be divided on the basis of comparing the total statewide program costs to the cost for each county.

(4) In the event the combination of the state's funding and the county's funding exceeds the total cost of the program in that county, then the state's contribution to that county shall be reduced by an amount so that the total funding combination equals the program's cost in that county.

(5) In no event shall the state pay the counties an amount in excess of three hundred and fifty thousand dollars ($350,000).

AUTH: 80-7-507, MCA IMP: 80-7-503, 80-7-504, MCA

RULE VI REIMBURSEMENT TO LANDOWNERS (1) The landowner shall be reimbursed by the county following his compliance with Rule IV and the state's disbursement of money to the county.

(2) The county may determine the reimbursement of the landowners from the fund consisting of the state's share and the county's share.

(3) In no event shall the landowner be paid an amount greater than his cost of supplies and services.

(4) In the event the program funds fail to equal the actual costs of applying the pesticide, the added expenses shall be incurred by the landowner.

AUTH: 80-7-507, MCA IMP: 80-7-504, MCA

3. The rationale for the proposed rules are set forth in the statement of reasons for emergency.

4. These rules are authorized under section 80-7-507, MCA. They implement Title 80, Chapter 7, Part 5, MCA.

The emergency action is effective June 20, 1986.

W. Ralph Peck
Deputy Director

Certified to the Secretary of State June 20, 1986.

Appendix C-3

RESOLUTION NO._____

WHEREAS, a serious grasshopper infestation exists on croplands used for the production of food and forage, including the headlands, ditches and rights-of-way adjacent to such lands; and

WHEREAS, the effective control of a grasshopper infestation requires remedial action prior to the grasshoppers reaching full adulthood; and

WHEREAS, the County has committed all available resources, taken all possible action to combat and to alleviate the situation, and local resources are not adequate to cope with the situation.

NOW, THEREFORE, BE IT RESOLVED by the County Commissioners that an emergency is hereby declared pursuant to Section 10-3-402, MCA, because the presence of grasshoppers throughout the County constitutes a serious insect pest infestation; and

BE IT FURTHER RESOLVED, that there shall be appropriated immediately to the Emergency Fund Number 2720 an amount equivalent to two (2) mills on the taxable valuation of the County outside the incorporated municipalities, pursuant to Section 10-3-405, MCA. Said two (2) mills will be levied during fiscal year 1987, and be utilized for a County Insect Pest Control Program; and

BE IT FURTHER RESOLVED, that by the passage of this Resolution, the County officially requests State financial assistance and participation in a County Insect Pest Control Program; and

BE IT FURTHER RESOLVED, that copies of this resolution be filed with the County Clerk and Recorder, County Assessor, and the Montana Disaster and Emergency Services Division in Helena.

PASSED AND ADOPTED by the _____County Board of County Commissioners this _____day of_____, 19___.

_____
Chairman

_____
Commissioner

(SEAL)

ATTEST:

_____
Commissioner

_____
Clerk and Recorder

Appendix C-4

MONTANA DEPARTMENT OF AGRICULTURE

CROP INSECT MANAGEMENT AGREEMENT

I. PARTIES: This agreement is entered into between the Montana Department of Agriculture hereafter referred to as Department and _____County hereafter referred to as County.

II. PURPOSE: This agreement is entered into for the control and management of Insect Pests threatening croplands located within _____County. The department has determined that an infestation of grasshoppers exists and a control program is needed to mitigate the damage that may occur. The county has determined an emergency infestation exists in its county and has levied the required 2 mill emergency funding for fiscal year 198____ in the amount of _____.

III. TARGET PEST: This agreement specifically provides that grasshoppers are the target pests.

IV. APPROVED PROGRAM: It is hereby agreed that a county conducting a cropland insect and spraying program in conformity to the rules specified in the attached emergency rules is approved for purposes of 80-7-503, MCA.

V. APPROVAL PESTICIDE: It is hereby agreed that only pesticides registered by EPA/State of Montana for grasshopper control in 1986 shall be permitted for application under this program. A list of registered pesticides will be provided to the county upon execution of this agreement.

VI. EFFECTIVE DATE AND TERMINATION: This agreement shall be effective when signed by both parties and shall terminate on November 15, 1986.

VII. INDEPENDENT CONTRACTOR: It is expressly understood that all persons participating in this program shall not, by virtue of this agreement, be considered employees of the State of Montana and entitled to state benefits or workers' compensation.

VIII. LIAISON: The department designates _____ to be the liaison for the department and the county designates _____to be the liaison and administrator of the program for the county.

IX. INCORPORATION OF RULES: It is agreed that the program shall be administered in a manner consistent with the emergency rules and specifically incorporates those attached rules into this agreement.

Appendix C-4 (cont.)

X. TIME OF PERFORMANCE: It is agreed that all landowners applying pesticides under this program must have contracted either to purchase the pesticide and/or to have it applied on or before July 9, 1986 for the year 1986. The actual application of the pesticide must be made on or before July 19, 1986. The landowner shall submit his claim, to the county as specified in Rule IV of the emergency rules, on or before September 1, 1986. Any claim of a landowner that fails to conform to these requirements or any other requirements of the rules shall be disallowed and the application of the pesticide on his land shall not be considered within this program.

XI. ACCESS TO RECORDS: The county shall maintain reasonable records of the landowner's claims and the county's performance of their duties under this agreement and shall allow access to the department, the legislative auditor, or where required by law, the legislative fiscal analyst, or any of their duly authorized agents or representatives.

XII. PAYMENTS: It is agreed that the state shall make payment to the counties in the following manner:

The state shall pay the county no more than:

(1) one-third the cost of the program in the county or,
(2) $1.25 an acre for every qualified program acre within the county or,
(3) an amount determined by the formula in Rule 5 of the emergency rules, whichever is the least.

Payment to the county shall be made by the state within 30 days following the receipt of all the claims submitted by all the counties participating in the cropland insect and spraying program.

XIII. SUBMISSION OF CLAIMS: The county shall submit a tabulation of all claims it receives from the landowner on or before October 1, 1986. This tabulation shall certify the total acres to which pesticides were applied under this program in the county, the number of participating landowners and the total monetary amount of claims submitted by the landowners.

XIV. VENUE: The parties agree that in the event of litigation concerning this agreement, venue shall be in the First Judicial District in and for the county of Lewis and Clark, State of Montana.

XV. MODIFICATION AND PREVIOUS AGREEMENTS: This instrument contains the entire agreement between the parties and no statements, promises, or inducements made by either party or agents of either party that are not contained in this agreement shall be valid or binding. This agreement may not be enlarged, modified, or altered except in writing, signed by both parties and attached as an amendment to the original of this agreement.

Appendix C-4 (cont.)

Dated this _____day of _____, 1986.

_____
Typed Name_____
County Commissioner of
_____County

_____
Keith Kelly
Director

_____
Typed Name_____
County Commissioner of
_____County

_____
Garth Jacobson
Department Attorney
Approved for Legal Content

_____
Typed Name_____
County Commissioner of
_____County

_____
Sandra Luchau
Administrator, Central
Services
Approved for Expenditure
Authorization

Appendix D. Toxicities and Potential Hazards of InsecticidesRegistered for Grasshopper Control

To better describe the toxicity and potential health and environmental hazards of insecticides registered for grasshopper control, the following appendix discusses the information published by the EPA, research scientists, and private institutions. A thorough description of each registered compound is not within the scope of this study, rather each compound is briefly described in tabular form with respect to their potential hazard to wildlife (Table D-1), environmental fate (Table D-2), human health (Table D-3), and residue tolerances for food and forage products (Table D-7). Also included in this appendix is a description of the sources of information, definitions of abbreviations and descriptions of toxicity categories for pesticides (Table D-4).

Sources of Information

The toxicities and hazard potentials of compounds registered for grasshopper control have been gathered from numerous sources. The majority of information has been generated to comply with the guidelines of FIFRA as amended (7 USC 136). FIFRA has established procedures for the registration, classification, and regulation of all pesticides. The EPA is the agency responsible for the implementation of FIFRA. Fact sheets, health advisories, and tox-one-liners are the major sources of pesticide information that are published by the EPA.

A wealth of information has been published on the toxicities of insecticides for mammals, birds, and aquatic organisms. However, inconsistencies in research methodology and approach limit their value. None-the-less, information has been collected from fact sheets, health advisories, review articles, research papers, and private company fact sheets. The values given reflect the most sensitive responses recorded.

Laboratory tests are run with test animals as to model the potential effect on the human body. Rats, pigs, dogs, monkeys, guinea pigs, and rabbits are commonly used. Toxicity tests are designed to produce either specific endpoints such as fatality or cancer; or toxicity reference levels, such as no observable effect level (NOEL).

Toxicity tests are administered for varying lengths to determine whether the compound causes acute or chronic toxicity. Acute tests generally involve a single dose or application to each member of a test group over a short period of time. Subchronic tests (used to determine the effects of multiple doses) usually last from about 3 to 90 days. Chronic studies are used to determine the effects of multiple or continuous doses and

generally last from 2 to 7 years (greater than half the lifetime of the test species.)

Administration of the compounds to the test animals include oral (forced into stomach or fed with diet), dermal (applied to the skin), inhalation (exposed to vapors or aerosol), and injection. Injection is rarely used as it bypasses the test animals natural protective mechanisms. Doses are expressed as either mg. of compound per kg. of body weight (mg/kg), or parts per million (ppm).

Acute toxicity studies are designed to identify the toxicity reference. Known as the median lethal dose (LD50), the dose which kills 50% of the test animals. Oral toxicity categories determined by the EPA are based on rat LD50's. Rabbits are most commonly used for the dermal LD50's. The acute LD50 doses result in the death of the animal and are thus relatively high (Table D-1). Because of this, acceptable intake values, such as food tolerances (Table D-4) are generally based on no observable effect studies rather than acute studies.

Subchronic studies are used to determine the level know as NOEL. These studies employ dosages lower than acute studies and provide information on systemic effects, cumulative toxicity, latency period, reversibility of toxic effects, and appropriate dose ranges to be used in chronic tests. Subchronic effects range from death to loss of body weight.

Chronic toxicity studies are also used in determining NOELs. Chronic studies are more useful in determining doses that are hazardous to reproductive success or what chemicals are cancer causing. The types of chronic studies include the following:

1) Teratogenicity tests. Used to determine the potential for malformations in an embryo or developing fetus.

2) Reproductive studies. Determine the effect of a chemical on reproductive success from production of reproductive cells, toxicity to the fetus, and survival of offspring.

3) Carcinogenicity tests. Determine the potential for a chemical to cause cancerous tumors when fed over a lifetime.

4) Mutagenic assays. Determine the ability of a chemical to cause physical and biochemical changes in an organisms genes that can be passed on to following generations.

Environmental Fate and Potential Health Hazards Associatedwith Insecticides

The following set of tables gives some idea of the environmental fate and potential health hazards of those compounds registered for grasshopper control. As stated previously, there are a number of inconsistencies and deficiencies in the available data. The majority of data given in the following tables were available from the EPA. Other sources of information exist; however, the cost of such data can be prohibitively high. The California Department of Food and Agriculture database is available, but the costs are beyond the scope of this document.

The following set of abbreviations and acronyms are frequently used in toxicology studies. Several of these will appear in the tables in this appendix. Other terms are defined in the glossary .

ADI: Acceptable Daily Intake. Maximum dose that a person could safely take every day throughout a lifetime without harm to health.

a.i.: Active Ingredient. The effective part of a pesticide formulation or the amount of technical material present in the formulation.

$EC^{50:}$ Median Effective Concentration. The concentration (ppm or ppb) of the toxicant on the environment (usually water) that produces a designated effect on 50 percent of the test organisms exposed (primarily microorganisms).

$LC^{50:}$ Median Lethal Concentration. A lethal concentration rate at which 50 percent of the test animals will be killed. Primarily used in testing fish and other aquatic organisms.

LD^{50}: Median Lethal Dose. The dosage of toxicant required to kill 50 percent of the animals in a test population when administered orally (mg toxicant/kg body weight).

LOAEL: Lowest Observable Adverse Effect Level. Lowest level at which toxic effects are observed.

ug/g: Micrograms Per Gram. Equivalent to 1 ppm. 1 ug = 0.001mg.

mg/kg: Milligrams Per Kilograms. Equivalent to 1 ppm. 1 mg = 0.000035 ounces. 1 kg = 2.2 pounds.

NOAEL: No Observable Adverse Effect Level. In a series of dose levels tested it is the highest level at which no adverse effect is observed.

NOEL: No Observable Effect Level. In a series of dose levels tested it is the highest level at which no effect is observed.

ppb: Parts Per Billion. Number of parts of a substance per billion parts of a given material (mg/kg or mg/l water).

ppm: Parts Per Million. Number of parts of a substance per million parts of a given material (mg/kg or mg/l water).

PADI: Provisional Acceptable Daily Intake. A value for ADI which has not been proven yet.

TMRC: Theoretical Maximum Residue Concentration. A calculated potential human exposure to pesticide residues in food based on residue tolerances.

Table D-1. Environmental half life and relative values of leaching potential or bioaccumulation of insecticides registered for grasshopper control.

Insecticide	Leaching Potential	Bioaccumulation	Half Life
Acephate	low	low	60 days
Azinphos-methyl	low	DG[1]	13 days
Carbaryl	low	low	14 days
Carbofuran	high	low	1-8 weeks
Chlorpyrifos	low	DG	to 279 days
Diazinon	moderate	DG	6 weeks
Dimethoate	low	DG	3-33 days
Disulfoton	low	DG	7 days
Fenvalerate	low	high	1-2 months
Malathion	moderate	low	0.5 days
Methyl Parathion	low	low	6-50 days
Mevinphos	high	DG	DG
Naled	low	low	8 hours
Nosema locustae	NA[2]	NA	NA
Parathion	low	low	3.5 days
Phorate	low	DG	6-48 days

1 dg = data gap
2 na = not applicable

Sources: EPA Fact Sheets, McEwen and Stephenson 1979, Sanborn et al. 1977.

Table D-2. Effect of registered insecticides on mammals (rat), birds (mallard duck), fish (rainbow trout, 96 hour exposure), and aquatic organisms (stonefly).

Insecticide	Mammalian Toxicity	Avian Toxicity		Fish Toxicity	Aquatic Toxicity
	Acute LD50 mg/kg	Acute LD50 mg/kg	Dietary LD50 ppm	Acute LC50 ppm	Acute LC50 ppm
Acephate	900	234	DG[1]	>1000	>100
Azinphos-methy	18	136	1940	0.014	0.008
Carbaryl	540	>2179	>5000	1.95	0.03
Carbofuran	6.4	0.4	16	0.09	0.01
Chlorpyrifos	135	76.6	136	3.0	0.05
Diazinon	66	3.5	191	0.6	0.06
Dimethoate	185	42	900	19[2]	0.14
Disulfoton	2.6	6.5	400	0.04[3]	0.04
Fenvalerate	>3200	9932	5500	0.00042	0.0014
Malathion	480	1485	5000	0.17	0.04
Methiocarb (Mesurol)	14	12.8	1071	0.4	0.02[4]
Methyl Parathion	57	6.6	336	2.7	0.00014
Mevinphos	608	4.6	1991	0.01	0.005
Naled	222	52.2	>5000	0.2[5]	0.166
Nosema locustae	NA	NA	NA	NA	NA
Parathion	4.0	2.1	262	2.0	0.008
Phorate	1.4	0.62	2.25	0.006	0.004

[1] NA = not available
[2] 24 hour exposure
[3] 48 hour exposure -- bluegill
[4] 48 hour exposure -- Daphnia
[5] 24 hour exposure
[6] 48 hour exposure

Sources: USEPA Fact Sheets and Health Advisories, Pimentel, D. 1971, Schafer et al. 1983, McEwen and Stephenson 1979, USDA-APHIS 1987, Hudson et al. 1984.

Table D-3. Toxicity categories for pesticides.

Hazard Indicators	I	II	III	IV
Oral LD^{50}	up to and including 50mg/kg	from 50 thru 500mg/kg	from 500 thru 5000 mg/kg	greater than 5000 mg/kg
Inhalation LD^{50}	up to and including .2 mg/liter	from .2 thru 2 mg/liter mg/liter	from 2.0 thru 20 mg/liter	greater than 20 mg/liter
Dermal LD^{50}	up to and including 200 mg/kg	from 200 thru 2000	from 2000 thru 20,000	greater than 20,000
Eye Effects	Corrosive: corneal opacity not reversible within 7 days	Corneal opacity reversible within 7 days; irritation persisting for 7 days	No corneal opacity; irritation reversible within 7 days	No irritation
Skin Effects	Corrosive	Severe irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

Source: Sine, C. 1988.

Table D-4. Acute and chronic toxicity categories for insecticides registered for grasshopper control.

Insecticide	Acute			Chronic		
	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation
Acephate	III	III	IV	DG[1]	DG	DG
Azinphos-methyl	I	I	DG	DG	DG	DG
Carbaryl	II	III	DG	DG	DG	DG
Carbofuran	I	I	I	DG	DG	DG
Chlorpyrifos	II	II	DG	DG	DG	DG
Diazinon	II	III	III	DG	DG	DG
Dimethoate	II	II	DG	DG	DG	DG
Disulfoton	I	I	DG	DG	DG	DG
Fenvalerate	II	III	DG	DG	DG	DG
Malathion	III	III	DG	DG	DG	DG
Methiocarb	I	III	DG	DG	DG	DG
Methyl-Parathion	I	I	I	DG	DG	DG
Mevinphos	I	I	I	DG	DG	DG
Naled	II	II	DG	DG	DG	DG
Nosema locustae	III	III	DG	DG	DG	DG
Parathion	I	I	DG	DG	DG	DG
Phorate	I	I	I	DG	DG	DG

[1] Data Gap

Table D-5. Chronic toxicities of registered insecticides.

Insecticide	Oncogen-icity Assays	Mutagen-icity Assays	Lowest Terato-genic NOEL	Lowest Systemic NOEL	ChE Inibition NOEL
Acephate	Positive	Weak	Rabbit 10.0mg/kg	Rat 50.0mg/kg	Rat 5.0mg/kg
Azinphos -methyl	Positive	Negative	Rabbit 0.75mg/kg	Rabbit 1 .2mg/kg	Rabbit 1.24mg/kg
Carbaryl	Negative	Weak	Dog 3.1mg/kg	Dog 1.8mg/kg	Dog 5.0mg/kg
Carbofuran	Rat >100mg/kg	Positive	Rat 2mg/kg	Rat 1.2mg/kg	Rat 4.0mg/kg
Chlorpyrifos	Rat >15mg/kg	NA	Rat >15mg/kg	Rat 0.75mg/kg	Dog 0.01mg/kg
Diazinon	Negative	Positive	Rabbit >100mg/kg	Rat 0.02mg/kg	NA
Dimethoate	Positive	Positive	Cat 2.8mg/kg	Dog 50.0mg/kg	Dog 0.2mg/kg
Disulfoton	Positive	Positive	Rat 1.0mg/kg	Rat 3.1mg/kg	Rat 0.1mg/kg
Fenvalerate	Positive	Weak	Mice 50mg/kg/day	Rat 100mg/kg	NA
Malathion	Negative	Positive	Rat >900mg/kg	Rat 100mg/kg	Human 0.27mg/kg
Methyl-Parathion	Positive	Negative	Rat >15mg/kg	Rat 2.5mg/kg	Dog 0.3mg/kg
Mevinphos	Rat >15mg/kg	NA	Rabbit >1.0mg/kg	Rat 2.3mg/kg	Rat 0.5mg/kg
Naled	Mice >75mg/kg	Positive	Rabbit >10.0mg/kg	Rat 15mg/kg/day	Rat 0.2mg/kg/day
Parathion	Positive	NA	Rabbit >5.0mg/kg	Rabbit 23mg/kg/day	Dog 0.01mg/kg
Phorate	Rat >6.0mg/kg	NA	Dog >0.5mg/kg	Dog 0.05mg/kg	Dog 0.01mg/kg

Source: EPA Tox-1-Liners

Table D-6. Toxicity and acceptable exposure levels of registered insecticides to humans.

Insecticide	ADI mg/kg/day	PADI mg/kg/day		TMRC mg/day	NOAEL mg/l	DWEL mg/l	Reentry
Acephate							24 hrs
Azinphos-methyl							24 hrs
Carbaryl	0.1			5.5	9.6	3.5	dries
Carbofuran	0.005			0.34		0.18	24 hrs
Chlorpyrifos	0.003			0.56			24 hrs
Diazinon	0.002				0.0175	0.00315	settles
Dimethoate	0.02						96 hrs
Disulfoton		0.00004			0.025	0.0014	24 hrs
Fenvalerate	0.025						dries
Malathion	0.02						
Methyl-Parathion		0.0015	0.3			0.009	48 hrs
Mevinphos							48 hrs
Naled				1.1			24 hrs
Nosema locustae							
Parathion	0.005						48 hrs
Phorate							7 days

Table D-7. Insecticide residue tolerances (ppm) for wheat grain, sugar beets, and alfalfa hay.

Insecticide	Wheat Grain	Sugar Beets	Alfalfa Hay
Azinphos-methyl	0.2[1]	---	2.0
Carbaryl	3.0	100.0[2]	100.0
Carbofuran	0.2	---	40.0
Chlorpyrifos	---	1.0[1]	15.0
Diazinon	---	0.5	10.0
Dimethoate	2.0[1]	---	2.0
Disulfoton	0.3	---	---
Malathion	8.0	1.0	135.0
Nosema locustae	exempt	exempt	exempt
Naled	---	0.5	---
Parathion[3]	1.0	0.1	1.25
Phorate	0.05	0.3	1.0

[1] Not registered for grasshopper control for this crop.
[2] Tops only.
[3] And methyl analog.

Source: 40 CFR 180.

Appendix E. Enterprise Cost Figures for Wheat and Barley

Table E-1. Enterprise cost figures for dryland barley following fallow.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
1 GROSS RECEIPTS FROM PRODUCTION:					
BARLEY	BU.	2.220	37.300	82.81	
STRAW	TN.	24.610	0.130	3.20	
TOTAL RECEIPTS				86.01	
2. VARIABLE COSTS:					
PREHARVEST:					
SEED	LBS.	0.055	57.000	3.13	0.08
NITROGEN	LBS.	0.219	16.780	3.67	0.10
PHOSPHATE	LBS.	0.286	14.370	4.11	0.11
POTASH	LBS.	0.119	1.490	0.18	0.00
HERBICIDE	ACRE	3.840	1.000	3.84	0.10
FERTILIZER APPL.	ACRE	2.560	0.070	0.18	0.00
MACH FUEL & LUBE	ACRE			6.78	0.18
MACH REPAIRS	ACRE			6.15	0.16
MACHINERY LABOR	HRS	4.640	1.689	7.84	0.21
INTEREST ON OP. CAP.	DOLS	0.087	15.609	1.37	0.04
TOTAL PREHARVEST				37.25	1.00
HARVEST:					
BALER TWINE-WIRE	BL.	23.800	0.010	0.24	0.01
CUST COMB & HAUL	ACRE	14.370	0.150	2.16	0.06
MACH FUEL & LUBE	ACRE			1.92	0.05
MACH REPAIRS	ACRE			2.05	0.05
MACHINERY LABOR	HRS	4.640	0.440	2.04	0.05
INTEREST ON OP. CAP.	DOLS	0.087	0.000	0.00	0.00
TOTAL HARVEST				8.40	0.23
TOTAL VARIABLE COSTS				45.65	1.22
3. CAPITAL OWNERSHIP COSTS (REPL., INT., INS., TAXES)					
TRACTORS				4.88	0.13
MACHINERY				28.58	0.77
TOTAL CAPITAL OWNERSHIP COSTS				33.46	0.90
4. OTHER COSTS					
LAND CHARGE (SHARE RENT)				25.83	0.69
GEN FARM OVERHEAD				7.60	0.20
TOTAL OTHER COSTS				33.43	0.90
5. TOTAL OF ABOVE COSTS				112.54	3.02

FOOTNOTES: 22% OF STRAW HARVESTED, 0.57 TONS/AC. 06/01/84
FEOS
70% OWNED, 5% CASH RENTED, 25% SHARE RENTED 10/19/84

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TITLE BARLEY - MONTANA - FOLLOWING FALLOW FINL1983

Table E-2. Enterprise cost figures for irrigated barley.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
1. GROSS RECEIPTS FROM PRODUCTION:					
BARLEY	BU.	2.220	68.300	151.63	
STRAW	TN.	23.500	0.290	6.81	
TOTAL RECEIPTS				158.44	
2. VARIABLE COSTS:					
PREHARVEST:					
SEED	LBS.	0.055	80.400	4.42	0.06
NITROGEN	LBS.	0.219	66.480	14.56	0.21
PHOSPHATE	LBS.	0.286	39.630	11.33	0.17
POTASH	LBS.	0.119	10.220	1.22	0.02
HERBICIDE	ACRE	3.640	1.000	3.64	0.05
INSECTICIDE	ACRE	0.100	1.000	0.10	0.00
IRRIGATION WATER	ACRE	8.650	0.540	4.67	0.07
FERTILIZER APPL.	ACRE	2.990	0.350	1.05	0.02
MACH FUEL & LUBE	ACRE			7.62	0.11
MACH REPAIRS	ACRE			6.51	0.10
IRRIG FUEL COST	ACRE			5.29	0.08
IRRIG LUBE COST	ACRE			0.08	0.00
IRRIG REPAIR COST	ACRE			5.76	0.08
MACHINERY LABOR	HRS	4.640	2.031	9.42	0.14
IRRIG LABOR	HRS	4.640	0.690	3.20	0.05
INTEREST ON OP. CAP.	DOLS	0.087	18.389	1.61	0.02
TOTAL PREHARVEST				80.48	1.18
HARVEST:					
BALER TWINE-WIRE	BL.	23.800	0.030	0.71	0.01
CUSTOM SWATHING	ACRE	6.000	0.020	0.12	0.00
CUST COMB & HAUL	ACRE	16.570	0.150	2.49	0.04
MACH FUEL & LUBE	ACRE			3.44	0.05
MACH REPAIRS	ACRE			3.82	0.06
MACHINERY LABOR	HRS	4.640	0.853	3.96	0.06
INTEREST ON OP. CAP.	DOLS	0.087	0.000	0.00	0.00
TOTAL HARVEST				14.54	0.21
TOTAL VARIABLE COSTS				95.02	1.39
3. CAPITAL OWNERSHIP COSTS (REPL., INT., INS., TAXES)					
TRACTORS				6.44	0.09
MACHINERY				36.93	0.54
IRRIGATION EQUIP				7.09	0.10
TOTAL CAPITAL OWNERSHIP COSTS				50.46	0.74
4. OTHER COSTS					
LAND CHARGE (SHARE RENT)				42.14	0.62
GEN FARM OVERHEAD				13.90	0.20
TOTAL OTHER COSTS				56.04	0.82
5. TOTAL OF ABOVE COSTS				201.52	2.95

FOOTNOTES: 35% STRAW HARV.,0 83 TONS/AC. 92% OWNED 4% CASH RENT 4% SH. RENT 06/01/84
IRR ASSUMP: 100%SURF.(54% PURCHASED) 60%SIDE-ROLL 40%FLOOD 11'LFT FEOS

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TITLE: BARLEY - MONTANA - IRRIGATED FINL1983

Table E-3. Enterprise cost figures for dryland hard red spring wheat following fallow.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
1. GROSS RECEIPTS FROM PRODUCTION:					
WHEAT	BU	3.840	25.300	97.15	
STRAW	TN	22.500	0.010	0.23	
TOTAL RECEIPTS				97.38	
2. VARIABLE COSTS:					
PREHARVEST:					
SEED	LBS.	0.076	61.100	4.64	0.18
NITROGEN	LBS.	0.219	12.540	2.75	0.11
PHOSPHATE	LBS.	0.286	11.520	3.29	0.13
HERBICIDE	ACRE	2.860	1.000	2.86	0.11
FERTILIZER APPL.	ACRE	2.190	0.070	0.15	0.01
MACH FUEL & LUBE	ACRE			6.85	0.27
MACH REPAIRS	ACRE			5.72	0.23
MACHINERY LABOR	HRS	4.640	1.675	7.77	0.31
INTEREST ON OP CAP	DOLS	0.087	13.763	1.20	0.05
TOTAL PREHARVEST				35.24	1.39
HARVEST:					
CUST COMB & HAUL	ACRE	11.660	0.140	1.63	0.06
MACH FUEL & LUBE	ACRE			1.41	0.06
MACH REPAIRS	ACRE			1.53	0.06
MACHINERY LABOR	HRS	4.640	0.309	1.43	0.06
INTEREST ON OP. CAP.	DOLS	0.087	0.000	0.00	0.00
TOTAL HARVEST				6.01	0.24
TOTAL VARIABLE COSTS				41.25	1.63
3. CAPITAL OWNERSHIP COSTS (REPL., INT., INS, TAXES)					
TRACTORS				5.70	0.23
MACHINERY				26.25	1.04
TOTAL CAPITAL OWNERSHIP COSTS				31.95	1.26
4. OTHER COSTS					
LAND CHARGE (SHARE RENT)				31.13	1.23
GEN FARM OVERHEAD				7.93	0.31
TOTAL OTHER COSTS				39.06	1.54
5. TOTAL OF ABOVE COSTS				112.27	4.44

FOOTNOTES 5% OF STRAW HARVESTED, .24 TON/AC 06/01/84
FEDS
57% OWNED, 6% CASH RENT, 37% SHARE RENT 10/19/84

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TITLE HARD RED SPRING WHEAT MONTANA FOLLOWING FALLOW FIRM 1983

Table E-4. Enterprise cost figures for dryland hard red spring wheat recrop.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
1 GROSS RECEIPTS FROM PRODUCTION:					
WHEAT	BU.	3 840	18 760	72 04	
STRAW	TN.	24.620	0.020	0 49	
TOTAL RECEIPTS				72 53	
2. VARIABLE COSTS.					
PREHARVEST.					
SEED	LBS.	0.076	59 400	4 51	0 24
NITROGEN	LBS	0.219	34.520	7 56	0 40
PHOSPHATE	LBS.	0.286	21 530	6 16	0 33
POTASH	LBS	0.119	1.330	0.17	0 01
FERTILIZER APPL.	ACRE	2.130	0 040	0 09	0 00
HERBICIDE	ACRE	3.190	1.000	3 19	0.17
INSECTICIDE	ACRE	0.580	1.000	0 58	0.03
CUSTOM TILLAGE	ACRE	0.360	1.000	0 36	0.02
MACH FUEL & LUBE	ACRE			3 38	0 18
MACH REPAIRS	ACRE			3 70	0.20
MACHINERY LABOR	HRS	4 640	0 825	3 83	0 20
INTEREST ON OP. CAP	DOLS	0.087	8.315	0 73	0.04
TOTAL PREHARVEST				34.25	1.83
HARVEST:					
CUST COMB & HAUL	ACRE	10.450	0.080	0 84	0 04
MACH FUEL & LUBE	ACRE			1.31	0 07
MACH REPAIRS	ACRE			1.46	0.08
MACHINERY LABOR	HRS	4 640	0.279	1 30	0 07
INTEREST ON OP CAP.	DOLS	0.087	0.000	0 00	0.00
TOTAL HARVEST				4 90	0.26
TOTAL VARIABLE COSTS				39 15	2.09
3. CAPITAL OWNERSHIP COSTS (REPL., INT., INS., TAXES)					
TRACTORS				3 00	0.16
MACHINERY				22 94	1 22
TOTAL CAPITAL OWNERSHIP COSTS				25.94	1.38
4. OTHER COSTS					
LAND CHARGE (SHARE RENT)				22.41	1.19
GEN FARM OVERHEAD				5.88	0.31
TOTAL OTHER COSTS				28.29	1 51
5. TOTAL OF ABOVE COSTS				93 38	4 98

FOOTNOTES: 14% OF STRAW HARVESTED, 0.14 TON/AC — 06/01/84 FEOS

51% OWNED, 6% CASH RENT, 43% SHARE RENT — 10/19/84

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TITLE: HARD RED SPRING WHEAT - MONTANA - FOLLOWING CROP — FINL1983

Table E-5. Enterprise cost figures for dryland hard red winter wheat following fallow.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
1. GROSS RECEIPTS FROM PRODUCTION					
WHEAT	BU.	3.710	32 770	121 58	
STRAW	TN.	23 620	0 020	0 47	
TOTAL RECEIPTS				122.05	
2. VARIABLE COSTS:					
PREHARVEST:					
SEED	LBS.	0.077	54.900	4 23	0.13
NITROGEN	LBS	0.219	32.400	7 10	0 22
PHOSPHATE	LBS.	0 286	21.300	6 09	0.19
POTASH	LBS.	0.119	1.700	0.20	0 01
FERTILIZER APPL.	ACRE	2.900	0.110	0 32	0.01
HERBICIDE	ACRE	4.300	1 000	4 30	0 13
HERBICIDE APPL.	ACRE	1.580	0.120	0.19	0.01
TRACE ELEMENTS	ACRE	0 270	1 000	0 27	0.01
HIRED MANAGEMENT	ACRE	0.070	1.000	0.07	0 00
MACH FUEL & LUBE	ACRE			8.38	0.26
MACH REPAIRS	ACRE			6.31	0 19
MACHINERY LABOR	HRS	4 640	1.868	8.67	0.26
INTEREST ON OP. CAP.	DOLS	0.087	32.808	2.87	0.09
TOTAL PREHARVEST				48.99	1.49
HARVEST:					
CUST COMB & HAUL	ACRE	14.720	0.200	2.94	0.09
MACH FUEL & LUBE	ACRE			1.51	0.05
MACH REPAIRS	ACRE			1.56	0.05
MACHINERY LABOR	HRS	4 640	0.334	1.55	0.05
INTEREST ON OP. CAP.	DOLS	0.087	0.000	0.00	0.00
TOTAL HARVEST				7.56	0.23
TOTAL VARIABLE COSTS				56.55	1.73
3. CAPITAL OWNERSHIP COSTS (REPL., INT , INS., TAXES)					
TRACTORS				8 26	0.25
MACHINERY				27.77	0.85
TOTAL CAPITAL OWNERSHIP COSTS				36.03	1 10
4. OTHER COSTS					
LAND CHARGE (SHARE RENT)				35 69	1 09
GEN FARM OVERHEAD				9.47	0 29
TOTAL OTHER COSTS				45.16	1.38
5. TOTAL OF ABOVE COSTS				137.74	4.20

FOOTNOTES: 4% OF STRAW HARVESTED, 0 56 TON/ACRE ASSUMES 146.000 ACRES PLACED IN PIK. 71% OWNED, 1% CASH RENT, 28% SHARE RENT

06/01/84
FEOS
10/24/84

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TITLE HARD RED WINTER WHEAT - MONTANA - NONIRRIGATED
(98% FOLLOWING SUMMER FALLOW)

FINL1983

Appendix F. Reasons for the Cancellation of Dieldrin

Many commenters at scoping sessions held by the MDA felt that Dieldrin should be returned for the control of grasshoppers. The following appendix describes the reasons for cancellation of Dieldrin by the EPA.

On October 18, 1974 the registration of Dieldrin was suspended and production prohibited for all pesticide products that contained Dieldrin (39 FR 37246). This decision was handed down following studies and hearings on the toxicology of Dieldrin.

Dieldrin was determined to be a "risk" amounting to a "substantial question of safety" following studies which showed that Dieldrin caused cancerous tumors in mice. Dieldrin was also observed to cause learning disabilities in monkeys, reproduction disabilities in dogs and mice, and danger posed to species such as the bald eagle. Newborns were shown to be the most sensitive to Dieldrin as a carcinogen. Dieldrin was also shown to be transferred to the fetus during pregnancy (39 FR 3748 and Sanborn et al. 1977).

The national cancer institute determined that the estimated daily dietary intake of Dieldrin subjects the human population to an extremely high cancer risk. In 1971 Deichman and MacDonald reported that the average human carried between 9.7 and 27.0 ppm of Dieldrin in their body fat. This seems fairly significant in light of tumors that formed in mice with concentrations of Dieldrin as low as 0.1 ppm. Exposure to Dieldrin for as short as several weeks is sufficient to cause highly significant carcinogenic effects to test animals.

Dieldrin is also highly persistent in the environment. Dieldrin has a half life of greater than 6 months in natural waters (McEwen and Stephenson 1979). Depending on pH, organic matter content, and temperature, Dieldrin may have a half life in soils of 1 to 13 years (Sanborn 1977). Some of the breakdown products of Dieldrin are more toxic than Dieldrin itself. Photodieldrin, a photolysis product of Dieldrin, is 2X more toxic to fish and 5X more toxic to mammals than Dieldrin (39 FR 3748).

Finally, the EPA determined that there was no agricultural necessity for the major uses of Dieldrin. Many other compounds exist and were being used in greater percentages than Dieldrin. The cotton bollweevil had also developed resistance to Dieldrin.

Appendix G. Tentative Outline for an IPM Program:A General Integrated Pest Management Strategy for Montana

I Surveying; pest populations are observed and verified prior to taking any action. This is accomplished by scouts and participating producers.

A. Identify populations, hatches, hatch areas, proximity to various crops, and the overall scope of the problem.

B. Determine whether a set economic threshold is being exceeded.

C. Document the above and take no action without verification.

II Guidelines for taking action. The MDA will not implement or assist in any actual control but will simply observe and advise.

A. Determine what alternatives or combination of alternatives are available.

1. Cultural; tillage, crop rotations, planting date, trap strips, etc....

2. Biological; bacteria, fungi, protozoans (Nosema locustae), parasitic and predatory insects, organisms currently under study.

3. Chemical; repellents and natural and synthetic insecticides.

B. Evaluate the potential environmental, economic, social, and health impacts of each alternative.

C. Select alternatives based on efficacy, cost effectiveness, and least impact on health and environment. Consider the following:

1. least disruptive of natural controls (i.e. beneficial insects).

2. least hazardous to human health.

3. least damaging to non-target organisms.

4. least damaging to general environment.

5. most likely to produce permanent reduction of the pest.

6. easiest to carry out effectively.

7. most cost effective in short and long run.

D. Chemical control strategies used only when a combination of other strategies is inadequate and the pest damage is likely to become intolerable.

III Monitor results of implemented strategies.

A. Look for control to acceptable levels, not eradication.

B. Look for alternatives that have the potential to improve results and/or lessen pest damage over time.

IV Incorporate a program of applied research. The research would be carried out by the MDA and interested producers and would be based on current research and information gleaned from the monitoring program.

A. The research program must focus on alternatives that have the least potential for adversely impacting the environment and human health, are efficacious, and cost effective.

B. Research will be carried out by qualified public and private institutions, organizations, and individuals on both experiment station and farms.

V The IPM program should continually be updated and grow with knowledge gained from research, literature search, and experience of producers.

VI Program implementation and administration.

A. The program would be administered by the MDA under the Montana Crop Insect Detection and Management Act (MCA 80-7-502).

B. The MDA would be ultimately accountable for the program and would enforce a process of accountability at all levels (field, supervisor, administrator).

C. The program administrator is responsible for developing a pest and resource management manual that outlines the principles and decision-making processes necessary for the effective implementation of the program.

1. This manual will serve as a training and decision-making tool for producers and scouts alike.

2. This manual will include a decision-making outline and checklist to be used by all levels of personnel involved with the program.

D. Field scouts will be hired by the MDA to monitor, and train producers to monitor pest populations, life cycles, damage, and effectiveness of control actions.

1. Scouts may be state university students, vo-ag students, or other qualified individuals.

2. Scouts will be located in and supervised by county extension, weed supervisors, or with MDA regional pesticide specialists.

3. Extension personnel will act as a liaison between producers, scouts and researchers.

4. Extension personnel and scouts will assist producers

in undertaking of on-farm experiments.

E. Field and supervisory personnel are accountable to the program administrator. They must be encouraged to develop alternatives and solutions that might work in their own area with individual producers.

VII Montana State University will undertake or assist with research as deemed necessary by the program. Funding for such research would be supplied by the program.

VIII A committee created by the MDA will assist in the implementation and development of the program.

A. This committee will be charged with identifying outcomes and guidelines consistent with the programs intent.

B. This committee will include representatives from extension, MDA agency staff, field scouts and supervisors, agriculturalists, environmentalists, IPM practitioners, the program administrator, and other interested parties. Members of the committee will be selected based on geographic location, agricultural background, and commitment to achieving an effective comprehensive IPM program.

IX This committee will monitor, evaluate, and revise the program on a regular basis.

X Adoption of the IPM program.

A. The success of the IPM program is dependent upon public commitment to providing adequate funding.

B. A minimum of three years is required to establish any IPM program for food crops.

1. 1st season; monitoring, setting injury levels, site/use variations, personnel needs, and resources.

2. 2nd season; refine injury levels and treatment strategies, make structural changes to system, train personnel.

3. 3rd season; refine and institutionalize implementation.

XI Producers would ultimately take complete control of the program with only guidance, standard pest surveillance, and research assistance from the MDA.

A. Producers would be responsible for field and treatment monitoring which they may do themselves or regional groups may hire scouts.

B. MDA would continue its research responsibility and would maintain an administrator who would coordinate regional efforts and would produce of a seasonal and an annual bulletin.

The majority of the above information was supplied by N. Matheson (1988).

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GLOSSARY

Acetylcholine--A chemical involved in transmission (carrying) of nerve impulses across junctions in the nervous system.

Acetylcholinesterase (AChE)--An enzyme produced at junctions in the nervous system that inactivates acetylcholine, thereby ending transmission of a nerve impulse once it has passed the junction.

AChE Inhibition--Binding of a compound to the AChE enzyme which renders it unable to act on Acetylcholine. This results in acetylcholine not being able to return to its active ionic state during a nerve synapse.

Active ingredient (a.i.)--The effective part of a pesticide formulation or the actual amount of the technical material present in the formulation.

Acute toxicity--The potential of a substance to cause injury or illness when given in a single dose or in multiple doses over a period of 24 hours or less; in aquatic studies, exposure to a given concentration for 96 hours or less.

Absorption--The taking up of liquids by solids or the passage of a substance into the tissues of an organism as the result of several processes; that is, diffusion, filtration, or osmosis.

Adsorption--Adhesion of substances to the surfaces of solids or liquids. Technically, the attraction of ions of compounds to the surfaces of solids or liquids.

Animal unit--Considered to be one mature cow (1,000 pounds) or the equivalent based on average daily forage consumption of 26 pounds dry matter per day.

Arthropod--Members of the phylum Arthropoda include the insects, the crustacea (crabs, lobsters, and shrimp), the arachnids (spiders, ticks, and scorpions), the millipedes, and centipedes. The arthropod is characterized by a rigid external body covering called a cuticle or exoskeleton, a segmented body, and paired, jointed appendages with at least one pair of functional jaws.

Assay--A test or measurement used to evaluate a characteristic of a chemical. See bioassay.

Attainment--A state of achieving.

Ataxia--Muscular incoordination; an inability to coordinate voluntary muscular movements.

Beneficial Insects--Those insects which in the course of their life cycle, carry, transmit, or spread pollen, act as predators of pest organisms, or affect crop growing conditions in any beneficial manner.

Bioaccumulation--The process of a plant or animal selectively taking in or storing a persistent substance. Over a period of time, a higher concentration of the substance is found in the organism than in the organisms environment.

Bioassay--A method for quantitatively determining the concentration of a substance by its effect on the growth of a suitable animal, plant, or microorganism under controlled conditions.

Carcinogen--A substance that causes cancer.

Cation--A positively charged ion; the ion in an electrolyzed solution that migrates to the cathode.

Chemical degradation--The breakdown of a chemical substance into simpler components through chemical reactions.

Cholinesterase (ChE)--Any enzyme that catalyzes the hydrolysis of choline esters; for example, acetylcholinesterase catalyzes the breakdown of acetylcholine to acetic acid and choline.

Chronic toxicity--Harmful effects of a chemical from prolonged exposure or repeated administration.

Class I Area--Areas of the United States (primarily national parks and wilderness areas) where ambient air concentrations of sulfur dioxide and particulate matter are allowed to be increased only minimally. Strict visibility standards are also effective around most class I areas.

Cropland--Any area planted with the intent to harvest. Crops planted and then grazed because of drought or insufficient growth will be considered cropland. Fallow land also will be considered cropland.

Degradation--See chemical degradation and microbial degradation.

Dermal exposure--The portion of a toxic substance that an organism receives as a result of the substance coming into contact with the organisms body surface.

Dermatitis--Inflammation of the skin.

Desorption--The removal of ions or compounds attached to the surfaces of particles of soil or organic matter.

Drift--Movement of pesticide sprays from the position of their target of application to an undesirable location.

EC50--Median effective concentration. The concentration (ppm or ppb) of the toxicant in the environment (usually water) that produces a designated effect (usually immobilization) on 50 percent of the test organisms exposed. This is used primarily for microorganisms for which it is difficult or impossible to determine if individual organisms are alive or dead.

Emergency--A serious insect pest infestation that imparts an imminent threat of disaster causing immediate peril to life or property which timely action can avert or minimize.

Endangered species--Any species of animal or plant that is in danger of extinction throughout all or a significant portion of its range.

Exposure--The estimation of the amount of chemicals that organisms receive during application of pesticides.

Forage--All browse and non-woody plants available to livestock or wildlife for grazing or harvesting for feed.

Forage production--The weight of forage that is produced within a designated period of time on a given area. The weight may be expressed as either green, air-dry, or oven-dry. The term may also be modified as to

time of production such as annual, current year's, or seasonal forage production.

Formulation--The form in which a pesticide is packaged or prepared for use. A chemical mixture that includes a certain percentage of active ingredient (technical chemical) with an inert carrier.

Half-life--The time required for a substance (such as an insecticide) in or introduced into a living or nonliving system to be reduced to half of its original amount whether by excretion, metabolic decomposition, or other natural process.

Herbivore--An animal that feeds exclusively on plants.

Horizons (soil)--A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes.

Hydrolysis--Decomposition or alteration of a chemical substance by water.

Infestation--A pest exists in such numbers, under certain conditions, and at certain times as to destroy or substantially damage or threaten livestock or agricultural crops.

Instar--The term for an insect before each of the moults (shedding of its skin) it must go through in order to increase in size. Upon hatching from its egg, the insect is in instar I and is so called until it moults, when it begins instar II, and so forth.

Insect--Any of the numerous small invertebrate animals generally having a segmented body, for the most part belonging to the class insecta, comprising six legged, winged and wingless forms, and to other classes of arthropods whose members are wingless and usually have more than six legs.

Insecticide--Any substance which is used to kill insects.

Insectivorous--Insect-eating; in common usage, includes animals that eat insects and sometimes other selected invertebrates.

Integrated Pest Management (IPM)--The selection, integration, and implementation of pest control tactics in a systems approach on the basis of anticipated economic, ecological, and sociological consequences.

Label--Written, printed, or graphic material on or attached to a pesticide, device, or its immediate container and any outside container or wrapper of any retail package of the pesticide.

LC50--Median lethal concentration. A lethal concentration rate at which 50 percent of the test animals will be killed. It is usually used in testing fish or other aquatic animals.

LD50--Median lethal dose. The dosage of toxicant, expressed in milligrams of toxicant per kilogram of body weight (mg/kg), required to kill 50 percent of the animals in a test population when administered orally.

Leach--Usually refers to the movement of chemicals through soil by water; may also refer to the movement of herbicides out of leaves, stems, or roots into the air or soil.

Lepidoptera--A large order of insects, including the butterflies and moths, characterized by four scale-covered wings and coiled, sucking mouthparts.

LOAEL--Lowest dose level at which toxic effects are observed.

Metabolite--A product of the chemical changes in living cells that provides energy and assimilates new material.

mg/kg--Milligrams per kilogram. Used to designate the amount of toxicant required per kilogram of body weight of test organisms to produce a designated effect; usually the amount necessary to kill 50 percent of the test animals. 1 mg/kg = 1 ppm. 1 mg = 0.000035 ounce. 1 kg = 2.2 pounds.

mg/kg/day--Milligrams per kilogram of body weight per day.

Microbial degradation--The breakdown of a chemical substance into simpler components by bacteria.

Microgram--One-millionth of a gram. Abbreviated as ug.

Micron--A unit of length equal to one-millionth (10-6) of a meter.

Microsporidian--A class of protozoan parasites of arthropods and fishes.

Mutagen--A substance that tends to increase the frequency or extent of genetic mutations (changes in hereditary material).

NOEL--The no-observed-effect level. In a series of dose levels tested, it is the highest level at which no effect is observed; that is, safe in the species tested.

Necrosis--Death of a cell or group of cells as a result of injury, disease, or other pathologic state.

Neurotoxin--Any toxic substance which destroys nerves or nerve tissue.

Omnivorous--Eating both animal and vegetable substances.

Oncogenic--Capable of producing or inducing tumors, either benign (noncancerous) or malignant (cancerous), in animals.

Outbreak--A sudden occurrence of pests in large populations.

Oven-dry weight--The weight of a substance after it has been dried in an oven at 105o C to equilibrium.

Percolation--The flow of a liquid through a porous substance.

Pest--any insect, rodent, nematode, snail, slug, plant, fungus, bacteria, virus or other organism which inhibits, impedes, or eliminates the growth and development of crop plants in a manner which reduces the economic value of the plant commodity.

Pesticide--Any substance or mixture of substances used in controlling insects, rodents, fungi, weeds, or other forms of plant or animal life that are considered to be pests.

Phenology--The study of the relationship between climatic conditions and periodic biological phenomena (such as grasshopper outbreaks). Phenology models rely on this relationship, based on weather and

biological data collected in the past, to predict recurrence of such phenomena.

Photodecomposition--The breakdown of a substance, especially a chemical compound, into simpler components by the action of radiant energy.

Phytotoxic--Poisonous or harmful to plants.

Ppb (parts per billion)--The number of parts of a substance per billion parts of a given material. 1 ppb = 1 ug/liter (water or air).

Ppm (parts per million)--A unit for measuring the concentration of a substance (such as a pesticide) in a carrier medium (such as food or water). For example, where the concentration is 1 ppm, the weight of the substance is 1 millionth the weight of the carrier medium; thus, 1 ppm is equal to 1 millionth of substance per kilogram of food or organism body weight, and it is equal to 1 milligram of substance per liter of water.

Producer--Any person who is involved in the practice of farming with the intention of producing raw agricultural commodities.

Protozoan--Members of the phylum Protozoa include the Mastigophora, opalinatea, sarcodinea, ciliophora, sporozoa, and cnidospora. They are single-celled or acellular organisms. They lack tissues and organs. Functionally differentiated parts of the protozoan are the organelles. A period of encystment is a commonly a part of the life cycle. With the exception of cysts, all protozoans are confined to moist places.

Rangeland--Any area on which the vegetation consists of native or introduced grasses, legumes, grasslike plants, forbs, or shrubs, and that is developed for range (grazing) use. Also counted as rangeland are native pastures or meadows that are occasionally cut or mechanically harvested and are grazed by livestock.

Residue level--Amount of pesticide that may remain on a crop after harvesting.

Riparian area--Land areas that are directly influenced by water. They usually have visible vegetative or physical characteristics reflecting this water influence. Stream sides, lake borders, or marshes are typical riparian areas.

Riparian habitat--Those terrestrial areas where the vegetation complex and microclimatic conditions are products of the combined presence and influence of perennial or intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Includes riparian zones plus one-half the transition zone (or ecotone) between riparian zones and upland habitat.

Runoff--That part of precipitation, as well as any other flow contributions, that appears in surface streams, either perennially or intermittently.

Scalping--A cultural practice used on rangeland to stimulate grass emergence and growth by mechanically manipulating the soil surface.

Scoping Session--A series of meetings which allows for pubic comment in determining the scope or range of material to be covered in the EIS and what potential alternatives are available to the current program.

Sensitive Area--A location or habitat which may sustain unreasonable adverse effects from the use of pesticides in close proximity to the location.

Suspended sediment--Sediment suspended in a fluid by the upward components of turbulent currents or by colloidal suspension.

Systemic NOEL--The No Observable Effects Level for the presence of a foreign substance in the whole body.

Systemic toxicity--Effects produced as a result of the distribution of a poison or foreign substance from the point of exposure to a distant site within the body.

Tachinidae--Family of flies, the larvae of which are parasitic.

Teratogen--a substance tending to cause developmental malformations in unborn human or animal offspring. Teratogenicity is the capacity of a substance to cause anatomical, physiological, or behavioral defects in animals exposed during embryonic development.

Tetany--A nervous affliction characterized by intermittent tonic spasms, which are usually paroxysmal and involve the extremities; most frequent in the young and frequently associated with pregnancy or lactation.

Threatened species--Those plant or animal species identified by the Secretary of the Interior as threatened, in accordance with the Endangered Species Act of 1973, and likely to become an endangered species throughout all or a significant portion of their range within the foreseeable future.

Tolerance level--Legal enforcement levels that are set by EPA well below levels that might cause harm to humans or the environment.

Toxicity--A characteristic of a substance that makes it poisonous.

Translocation--The transfer of substances from one location to another in the plant body.

Turbidity--Quality of not having translucent appearance of liquid due to growth of microorganisms. Having flaky or granular particles suspended in a clear liquid, giving it a cloudy appearance.

Understory--Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs, and low shrubs under a tree or brush canopy.

Volatility--The tendency of a substance to evaporate at normal temperatures and pressures.

Wetland or wetland habitat--Permanently wet or intermittently flooded areas where the water table (fresh, saline, or brackish) is at, near, or above the soil surface for extended intervals; where hydric wet soil conditions are normally exhibited, and where depths generally do not exceed 2 meters. Vegetation generally comprises emergent water-loving forms (hydrophytes) that require at least a periodically saturated soil condition for growth and reproduction. In certain instances, vegetation may be completely lacking.

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